Astronomy®

THE WORLD'S BEST-SELLING ASTRONOMY MAGAZINE /// JULY 2025

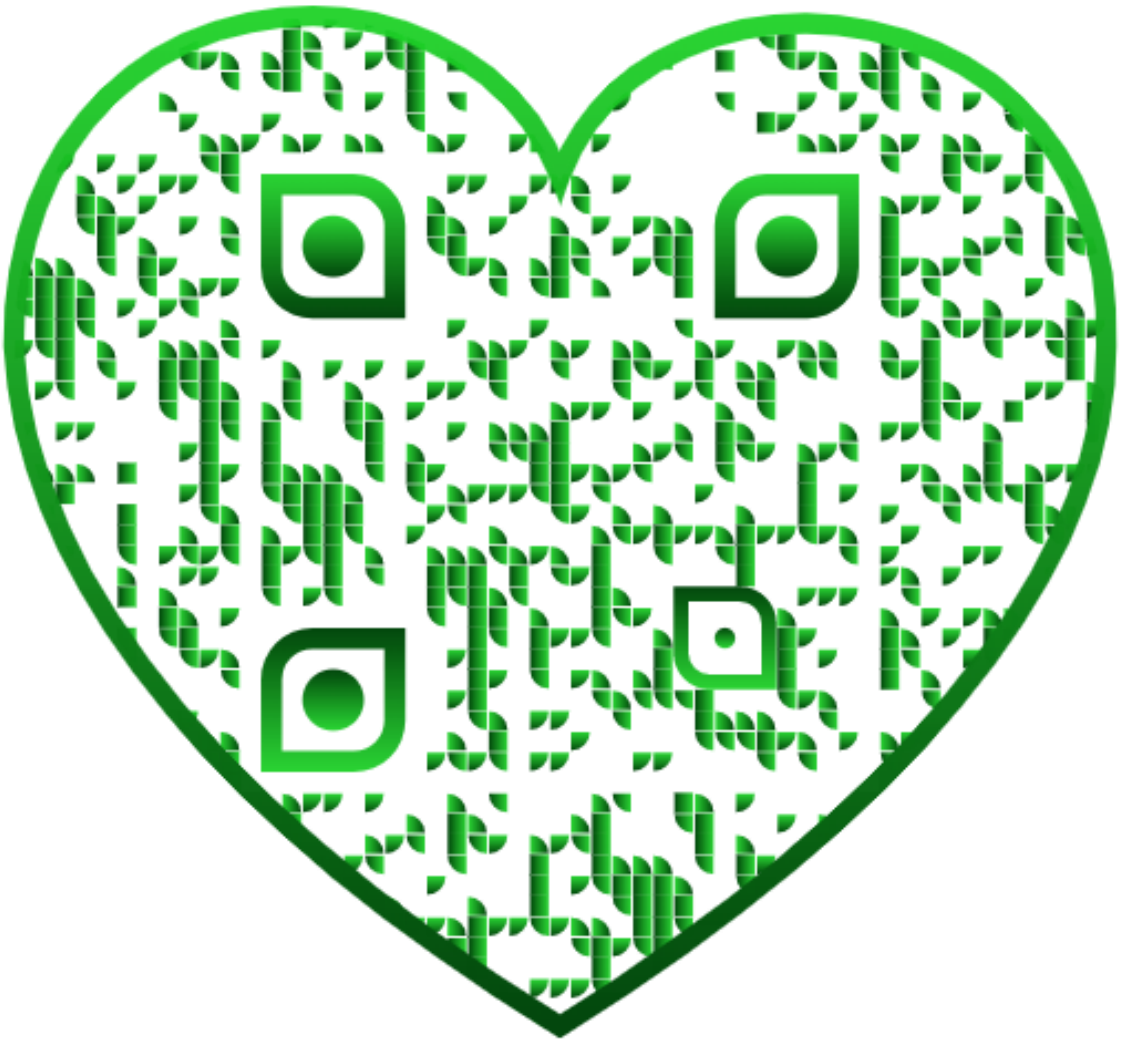
IS THE MILKY WAY A STRANGE GALAXY?

NEW CLUES ABOUT OUR OWN HOME

- OBSERVE ANDROMEDA'S DEEP-SKY TREASURES
- THE LYNDS CATALOG OF DARK NEBULAE
- EXPLORING STAR COLORS
- TARGET GREAT NGC STAR CLUSTERS
- REDCAT 91MM SCOPE REVIEWED

BONUS ONLINE CONTENT CODE p. 3

Vol. 53 · Issue 7

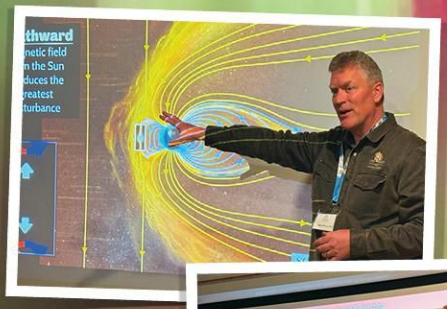


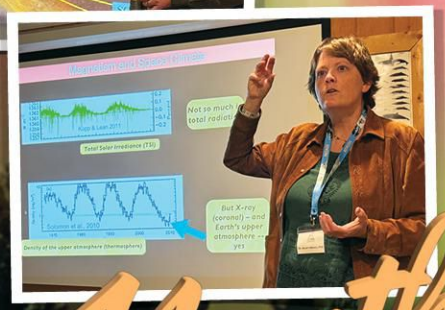
Ultimate Northern Lights Solar Science Adventure

It's all about the experience!

Join Lazy Bear Expeditions directly beneath the auroral oval at the high magnetic latitude of Churchill, Manitoba, for a life-changing northern lights experience!

Led by renowned solar scientists Dr. Mark Miesch and Dr. Sarah Gibson, this all-inclusive adventure offers solar science presentations, real-time space weather updates, and nightly viewing alongside these experts during the peak solar activity in autumn 2025.





Don't miss this opportunity to explore the science of the aurora and enjoy curated northern lights viewing, northern lights photography sessions, tundra helicopter tour and unique arctic adventures like dog mushing and Indigenous storytelling.

Book now to reserve your spot on this 'astronomical' experience, suitable for novices and experts alike!

UP North AND PERSONAL™

LazyBearLodge.com/Science

LAZY BEAR EXPEDITIONS
Churchill, Manitoba, Canada

JULY 2025
VOL. 53, NO. 7

Online Content Code: ASY2507
Enter this code at **www.astronomy.com/code** to gain access to web-exclusive content.

CONTENTS

52

ON THE COVER

Scientists are beginning to understand what is unique about our Milky Way Galaxy, photographed here arching over Arizona's Meteor Crater.
JOHN VERMETTE

FEATURES

12 COVER STORY
How weird is the Milky Way?
By studying what makes the Milky Way unique, astronomers are hoping to understand our galaxy's past and unravel the mystery of dark matter.
SHARMILA KUTHUNUR

19
Explore the wonders of Andromeda
There's a lot more to this constellation than one great galaxy. **MICHAEL E. BAKICH**

24
Observe the multihued sky
Patience with your eye and telescope will reveal stars of a different color.
RAYMOND SHUBINSKI

28
Sky This Month
Venus tracks through Taurus.
MARTIN RATCLIFFE AND ALISTER LING

30
Star Dome and Paths of the Planets
RICHARD TALCOTT; ILLUSTRATIONS BY ROEN KELLY

36
Exposing the interstellar medium
The penetrating eye of JWST brings Cassiopeia A's surroundings into focus.
RICHARD TALCOTT

38
Beverly Lynds and her dark nebulae
Correctly identifying Lynds' dark nebulae has become a labor of love for one amateur astronomer. **RODNEY POMMIER**

44
Discover great NGC star clusters
If you've never strayed beyond Messier objects, this list will be a revelation. **ROBERT REEVES**

48
The RedCat 91 is a refractor everyone should want
William Optics' newest refractor captures pinpoint stars and fine detail for imagers. **FRANK DIBBELL**

52
Ask Astro
Variable stars.

IN EVERY ISSUE

From the Editor **4**
Astro Letters **6**
Observing Basics **50**
MOLLY WAKELING
New Products **51**
Advertiser Index **51**
Reader Gallery **54**
Breakthrough **58**

7
QUANTUM GRAVITY
Everything you need to know about the universe this month: aurorae on Neptune, black holes in the Large Magellanic Cloud, exoplanets found nearby, and more.

ONLINE FAVORITES
Go to **www.Astronomy.com** for info on the biggest news and observing events, stunning photos, informative videos, and more.

The Space Store
Perfect gifts for your favorite science geeks.

Trips and Tours
Travel the world with the staff of *Astronomy*.

Sky This Week
A daily digest of celestial events.

Ask Astro Archives
Answers to all your cosmic questions.

Astronomy (ISSN 0091-6358, USPS 531-350) is published monthly by Firecrown Media Inc., 405 Cherry Street, Chattanooga, TN 37402. Periodicals postage paid at Chattanooga, TN and additional mailing offices. **POSTMASTER:** Send address changes to *Astronomy*, PO Box 850, Lincolnshire, IL 60069.

ONLINE FAVORITES, LEFT TO RIGHT: ASTRONOMY.COM; AARSTUDIO/DREAMSTIME.COM; ALLEXXANDAR/DREAMSTIME.COM; SRIPFOTO/DREAMSTIME.COM

Is the Milky Way weird?

The Milky Way's two largest satellite galaxies — the Magellanic Clouds — lie above the horizon in this panorama. Studying satellite galaxies can yield insight into their host galaxies, their dark matter halos, and their surrounding environments.
MATT DIETERICH

The Milky Way Galaxy is our home. We've known that for a long time, and in a fairly precise sense since Edwin Hubble's discovery of the nature of galaxies and the cosmic distance scale, in 1923. For a long time we believed the Milky Way was a simple spiral galaxy. About 20 years ago astronomers mapped the galaxy's arms with increased precision and found that we are in a barred spiral galaxy.

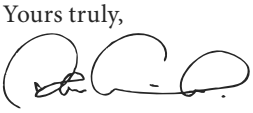
The Milky Way's bright disk, which we see as a band of stars and a luminous glow from inside, stretches at least 100,000 light-years from end to end. Our Sun and solar system lie about 27,000 light-years from the galactic center, which contains a supermassive black hole with a mass of about 4.3 million suns. The galaxy contains several hundred billion stars; the exact number is hard to say as the most numerous suns, M dwarfs, are very faint over long distances. The whole mess is suspended in a vast halo of dark matter that is far larger than the bright disk.

That's all fine and good. We go about our lives knowing that we're in a pretty stable situation, at least on the timeline of human lives and civilizations. But perhaps we don't know our home galaxy, one of at least 100 billion in the cosmos, as well as we may have thought.

Science journalist Sharmila Kuthunur unveils an intriguing story (page 12) this month suggesting the Milky Way may be an outlier among similar galaxies. The SAGA Survey, short for Satellites Around Galactic Analogs, is revealing surprises after a decade-long effort led by Risa Wechsler of Stanford University. After identifying and comparing 101 galaxies like the Milky Way and 378 of their satellite galaxies, Wechsler's team concluded that our galaxy is an outlier among its galactic siblings in a variety of ways.

I hope you'll enjoy this story and that its revelations may allow you to see the night sky in a slightly new way.

Yours truly,



David J. Eicher
Editor-in-Chief

Follow Dave on
Facebook:
facebook.com/davidjohneicher
X (formerly Twitter):
@deicherstar
Instagram:
eicher.david

FOLLOW *ASTRONOMY*

facebook.com/AstronomyMagazine
twitter.com/AstronomyMag
youtube.com/user/AstronomyMagazine
instagram.com/astronomy.magazine

Astronomy

Editor-in-Chief David J. Eicher
Assistant Design Director Kelly Katlaps

EDITORIAL
Senior Production Editor Elisa R. Neckar
Senior Editors Alison Klesman, Mark Zastrow
Associate Editors Michael E. Bakich, Daniela Mata
Editorial Assistant Samantha Hill

ART
Illustrator Roen Kelly
Production Director Kelly Kramer Weekley
Operations Specialist Melissa Valuch
Production Specialist Jodi Jeranek

CONTRIBUTING EDITORS
Bob Berman, Adam Block, Martin George, Tony Hallas, Phil Harrington, Korey Haynes, Alister Ling, Stephen James O'Meara, Martin Ratcliffe, Raymond Shubinski, Richard Talcott, Molly Wakeling

EDITORIAL ADVISORY BOARD
Buzz Aldrin, Marcia Bartusiak, Jim Bell, Timothy Ferris, Alex Filippenko, Adam Frank, John S. Gallagher III, Daniel W. E. Green, William K. Hartmann, Paul Hodge, Edward Kolb, Stephen P. Maran, Brian May, S. Alan Stern, James Trefil

Firecrown
Chief Executive Officer Craig Fuller
President David Bradford
Chief Strategy Officer Keith Beckman
Chief Commercial Officer Preston Brown
Chief Operations Officer Nicole McGuire
Chief Financial Officer Lan Phan
Vice President, Finance/Controller Amanda Joyce
Vice President, Creative Barry Carpenter
Group President, Hobby Division Nicole McGuire
Group President, Aviation Division David Carr
Group President, Marine Division Glenn Sandridge
Editorial Director Meg Scarbrough
Vice President, General Counsel Darren Caputo
Human Resources Director Suzie Matoh

ADVERTISING DEPARTMENT
Advertising Representative Kristi Rummel
Phone (608) 435-6220
Email kristi.rummel@firecrown.com

RETAIL TRADE ORDERS AND INQUIRIES
Selling *Astronomy* magazine or products in your store:
Email terri.meunier@firecrown.com

CUSTOMER SALES AND SERVICE
Phone (877) 246-4835
Outside U.S. and Canada (847) 313-3921
Customer Service AstronomyMagazine@Omeda.com

CONTACT US
Ad Sales adsales@astronomy.com
Ask Astro askastro@astronomy.com
Books books@astronomy.com
Letters letters@astronomy.com
Products products@astronomy.com
Reader Gallery readergallery@astronomy.com

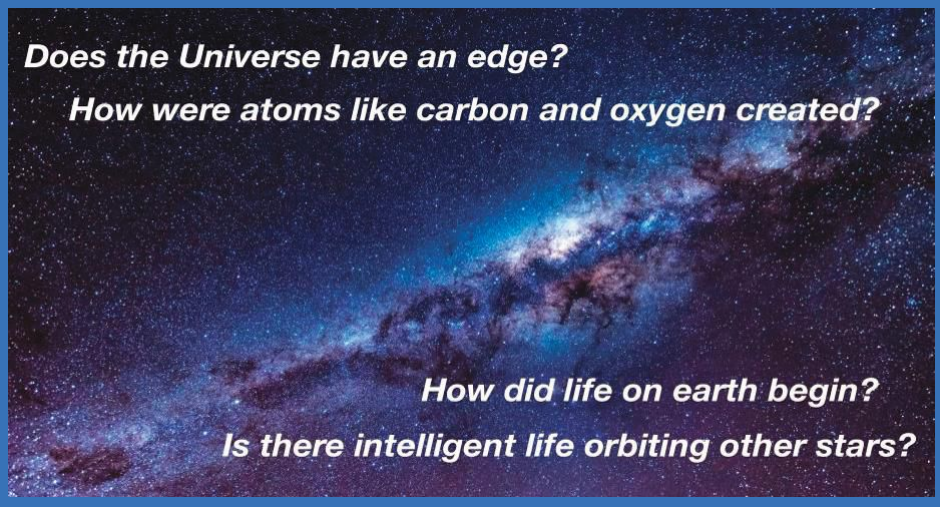
For reprints, licensing, and permissions:
PARS International at www.parsintl.com

Copyright © 2025 Firecrown Media Inc., all rights reserved. This publication may not be reproduced in any form without permission. Printed in the U.S.A. Allow 6 to 8 weeks for new subscriptions and address changes. Single copy: $6.99 (U.S.). Print + digital subscription rate: U.S.: 1 year $58.95. Canadian: Add $12.00 postage. Canadian price includes GST, payable in U.S. funds. All other international: Add $22.00 postage, payable in U.S. funds, drawn on a U.S. bank. BN 12271 3209 RT. Not responsible for unsolicited materials.

Adventures in Astronomy: Approaching Infinity

Tuesdays, 7:30 PM-9:00 PM, Eastern Time, over Zoom

June 10, 2025 thru September 30, 2025


Does the Universe have an edge?
How were atoms like carbon and oxygen created?
How did life on earth begin?
Is there intelligent life orbiting other stars?

Dr. George Roush will explore

1. Geo-centrism & the Copernican Revolution
2. Our sun & its planets
3. The birth, evolution & death of stars
4. Telescopes
5. Our Milky Way Galaxy
6. Other galaxies & their evolution
7. Dark matter: What is it?
8. Dark energy & the expanding universe
9. Relativity & black holes
10. The Big Bang: The beginning of spacetime
11. Is intelligent life orbiting other stars?

Email: astronomy.teacher0@gmail.com; Telephone: (203) 536-0006

To learn more and to register visit astronomyteacher.net.

Adventures in Astronomy is a non-profit 501(c)(3) organization.

The Rosette Nebula (NGC 2244) was named Oklahoma's state astronomical object because of its resemblance to the state flower, the Oklahoma rose. CTIO/NOIRLAB/DOE/NSF/AURA; IMAGE PROCESSING: T.A. RECTOR (UNIVERSITY OF ALASKA ANCHORAGE/NSF NOIRLAB), D. DE MARTIN & M. ZAMANI (NSF NOIRLAB)

We welcome your comments via email to **letters@astronomy.com**. *Please include your name, city, state, and country. Letters may be edited for space and clarity.*

A rosy outlook

I read the article about the Rosette Nebula in the February 2025 issue ("A blooming nebula"). It was interesting to me because in 2019, the Oklahoma City Astronomy Club asked State Representative Nicole Miller to sponsor a bill naming the Rosette Nebula the official state astronomical object of Oklahoma. The bill passed and was signed into law that year. **—Bill Murrell,** Oklahoma City, OK

"Ain't no way"

Thank you for introducing me to the AINTNO list in the February 2025 issue ("Treasures of the Milky Way"). It's a fascinating list of challenging targets for visual observers, and inspired me to look each one up. Some of them, like the Great Attractor, the heliopause, a neutrino, the vernal equinox, and Planet X, gave me a chuckle. It was interesting to see that only five AINTNO certificates have been awarded by the list's authors. (Certificates are awarded for a successful observation of just one object from the list.) **—Linda Dowell,** Pleasant Prairie, WI

Climate conundrum

Thank you for printing the article "Solving the climate equation" (April 2025). As the author writes, we need to talk about the present existential crisis facing life as we know it on Planet Earth, and as others have said, "There is no Planet B." Our lack of action on this universal reality for humanity is so hilariously well portrayed in the movie *Don't Look Up*. We have the knowledge to do what needs to be done. Thank you to the author, Katharine Hayhoe, for connecting the dots from our heads to our hearts. **—Carlton B. Turner,** Newark, DE

Erratum: *In the March 2025 article "30 years of exoplanets," the author states that verification of the existence of an exoplanet with Jupiter's size and orbit would require three transit observations that would take at least 10 years. It would actually take closer to 25 years to achieve this.*

ScopeBuggy

- For use with most tripods, DOBs and piers
- 10" Pneumatic tires for soft ride
- Load tested to 600+ pounds
- Assemble & disassemble in minutes
- Adjustable rear axle height (1½" to 7")
- Ideal for scopes up to 36"
- One person can quickly and easily move any sized scope

STILL #1

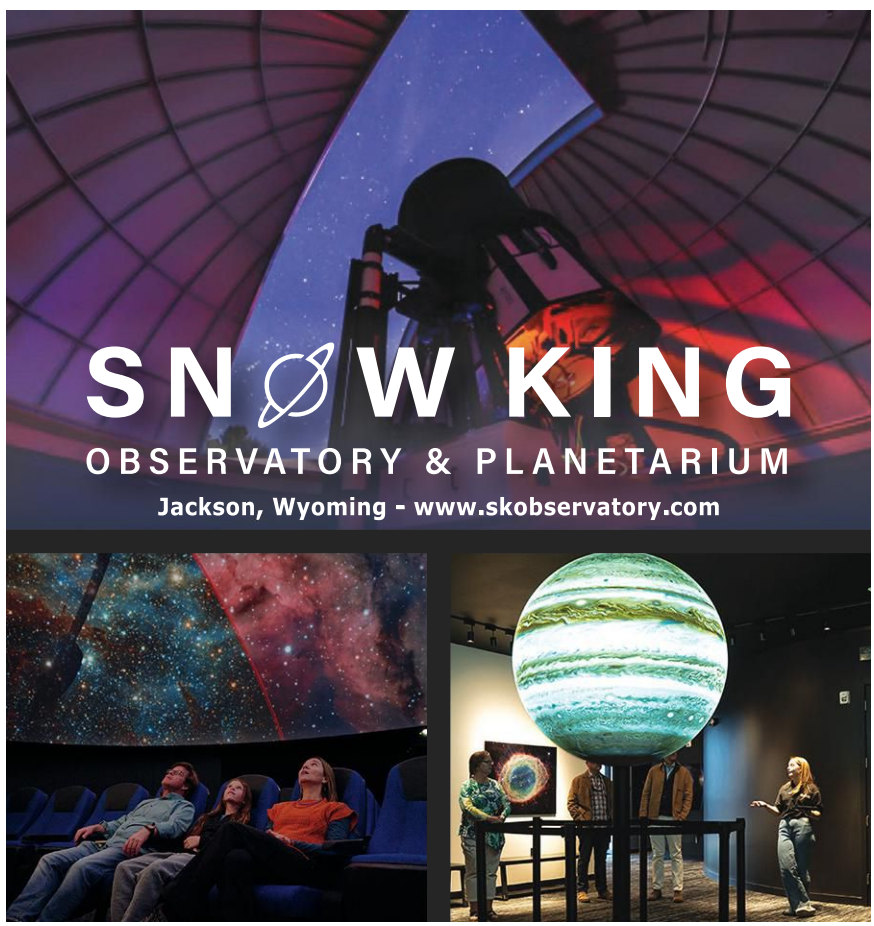
$345.00*
Plus S&H
Approx. $70 Shipping
USA
*Subject to change

Patent Pending

SCOPEBUGGY
P.O. BOX 834
Elephant Butte, NM
87935

915-443-9010

www.ScopeBuggy.com



SNAPSHOT

BIRTH OF A BINARY

JWST captured twisting jets that trace out the history of the stars that created them.

As stars form, they pull in material from their surroundings. But they also spew out jets of gas and dust, as seen in this James Webb Space Telescope image of Lynds 483. At the center of the jets is a pair of protostars, invisible within a disk of cold gas and surrounded by dense dust, which is noticeable by the way it dims the light of stars far behind this system to either side.

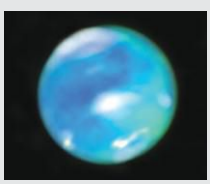
Over time, the stars have blown out material that has formed the jets at the top and bottom. Visible features include a shock front, shown in orange at upper right, where the jet has run into denser interstellar material and slowed. Asymmetries and other structural details in the jets allow astronomers to trace the stars' past behavior by creating models, tweaking the type and amount of material and radiation over time to reproduce what we see now. The two stars have been creating these jets for tens of thousands of years; it will take millions more for them to completely clear out their surroundings. —ALISON KLESMAN

NASA, ESA, CSA, STScI. BOTTOM FROM RIGHT: SPACEX; NASA, ESA, CSA, STSCI, HEIDI HAMMEL (AURA); HENRIK MELIN (NORTHUMBRIA UNIVERSITY), LEIGH FLETCHER (UNIVERSITY OF LEICESTER), STEFANIE MILAM (NASA-GSFC); ISAR AEROSPACE, SIMON FISCHER, WINGMEN MEDIA

HOT BYTES

TWO FOR ONE

Two NASA missions, SPHEREx and PUNCH, launched March 11 from Vandenberg Space Force Base on a SpaceX Falcon 9 rocket. SPHEREx will map the near-infrared sky and millions of galaxies, while PUNCH will study the Sun's corona and solar wind.



AURORAE UNVEILED

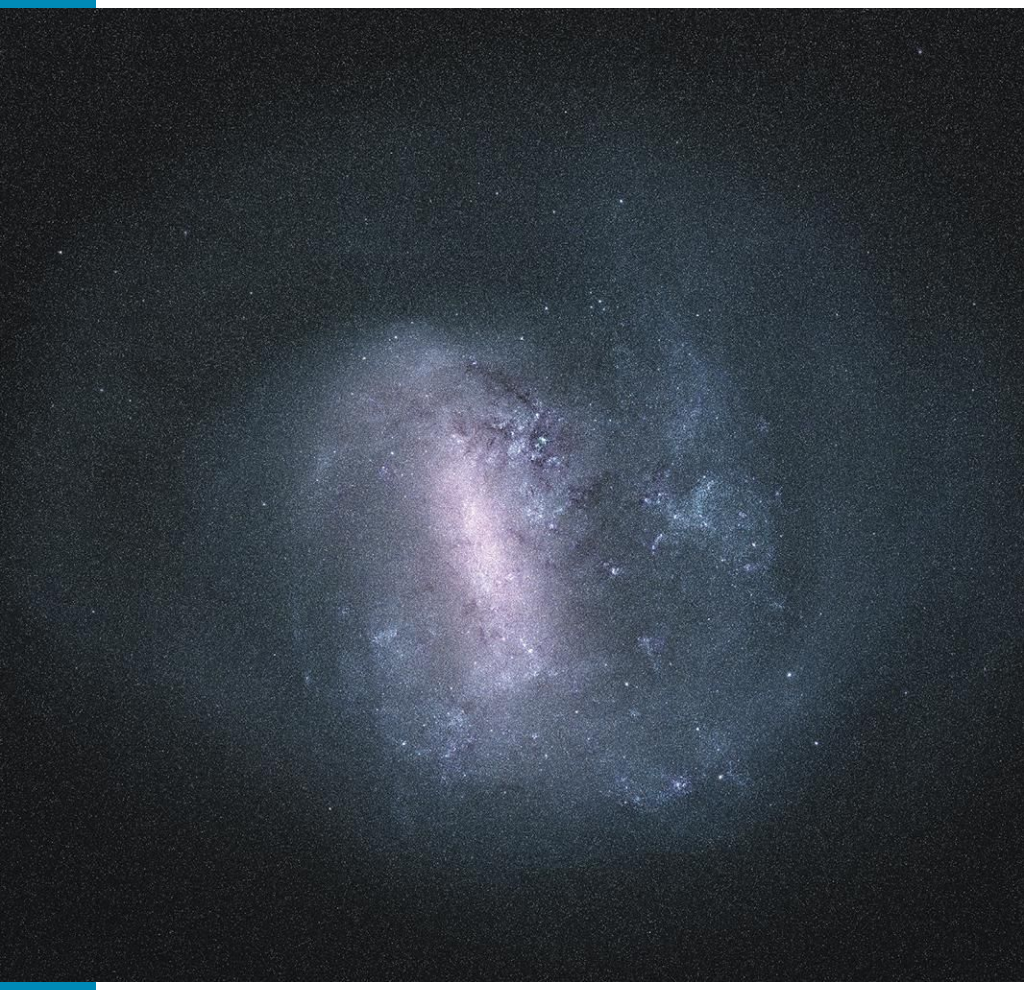
NASA's James Webb Space Telescope has captured the first images of bright auroral activity on Neptune. The data show the ice giant's upper atmosphere has cooled by hundreds of degrees since Voyager 2's 1989 flyby, making the aurorae fainter than expected.

FIRST FLIGHT FIZZLES

Isar Aerospace's first test flight March 30 from Norway's Andøya Spaceport was also the first orbital launch ever attempted from mainland Europe. The rocket lifted off successfully, but lost control about 20 seconds after launch and fell into the sea near the pad.

THE LMC MIGHT HAVE A SUPERMASSIVE BLACK HOLE

Fast-moving stars in the Milky Way originated in the Large Magellanic Cloud, where a central black hole may have kicked them out.



NEAR NEIGHBOR. The Large Magellanic Cloud is a dwarf galaxy gravitationally bound to the Milky Way. Astronomers have now uncovered strong evidence that it hosts a 600,000-solar-mass black hole. ESA/GAIA/DPAC

The Large Magellanic Cloud (LMC) is one of the Milky Way's closest neighbors. It's also one of the only galaxies outside our own where telescopes can resolve individual stars and small-scale structure.

While large galaxies host central supermassive black holes (SMBH) as a rule, dwarf galaxies like the LMC are more mixed. But a new analysis of data from the European Space Agency's Gaia space telescope indicates the LMC may indeed have a central black hole weighing 600,000 times as much as the Sun. The research, led by Jiwon Jesse Han of the Harvard-Smithsonian Center for Astrophysics, has been accepted for publication in *The Astrophysical Journal*.

SPEEDY STARS

The discovery comes from studying hypervelocity stars in the Milky Way. These stars are moving rapidly — up to 2.2 million mph (3.6 million km/h), instead of cruising along with the stars around them.

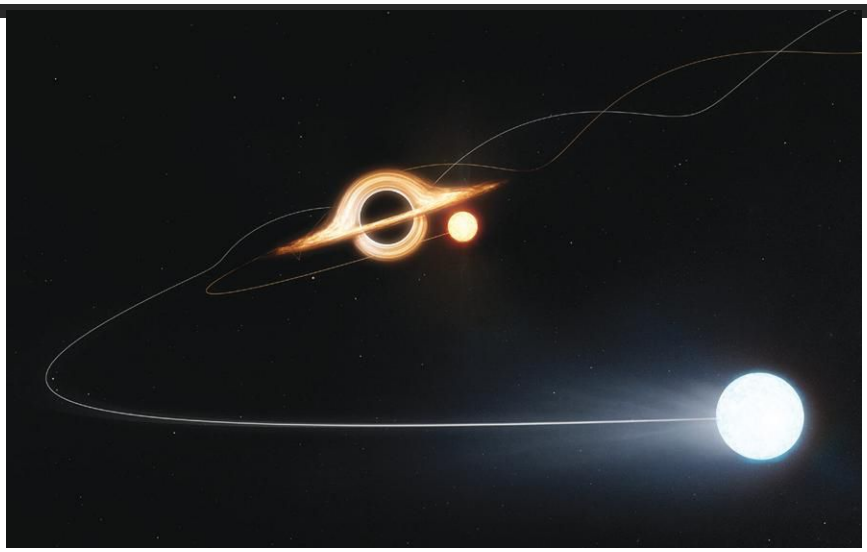
Astronomers thought that most hypervelocity stars resulted from an encounter with the Milky Way's SMBH, as black holes can "kick" a star to higher speeds than supernovae or interactions with other stars. But when Han, a graduate student at Harvard University, looked at a batch of hypervelocity stars in the Gaia data, he tracked their path back not to the Milky Way's core, but to the LMC.

Han's team found these stars clustered on the sky in a tight group, dubbed the Leo Overdensity. That gave a big clue to their origin. If the stars had come from the Milky Way's disk, they would be more spread out on the sky. "Only an ejection from the center of the LMC can produce an overdensity as tight as the Leo Overdensity," Han tells *Astronomy*.

In 2016, astronomers Douglas Boubert and Wyn Evans from the University of Cambridge proposed an SMBH in the LMC as the culprit for the Leo Overdensity. But more precise data was needed. "Using the latest data from Gaia, Jesse and his stellar team of co-authors have proven [our] outlandish theory," says Boubert.

FITTING IN

Every large galaxy contains an SMBH, whose size scales with the size of the



GAINING SPEED. One way astronomers think hypervelocity stars gain their speed is through interactions with a black hole, as in this artist's concept. Here, a binary system that came too close to a black hole is torn apart, with one star (orange) remaining in orbit around the black hole and the other (blue-white) flung away as a hypervelocity star. CFA/MELISSA WEISS

galaxy. But dwarf galaxies don't always follow this rule.

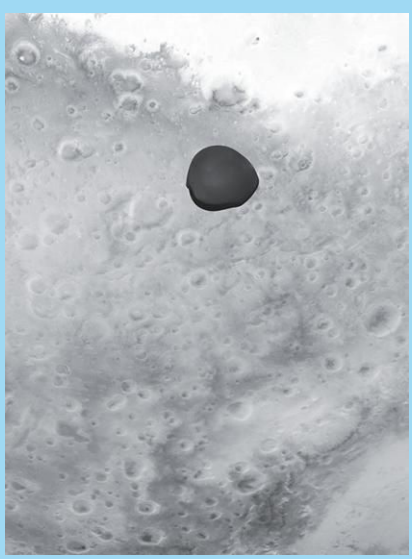
Han's team calculated the black hole mass needed to eject stars at the measured velocities, and found it should be roughly 600,000 solar masses. That turns out to be an excellent fit to the expected mass of an SMBH in the LMC, based on the known galaxy-black hole mass relationship.

"So, while it's rather surprising how we found evidence for the SMBH, the actual mass of the SMBH is totally within reason, and should've been somewhat expected," Han says.

Astronomers will seek to confirm the existence of the LMC's SMBH through additional observations. Promisingly, the data Han used is from only the first three years of Gaia's mission; more data will come in 2026 and at the end of the decade. That will let astronomers better pin down how stars move, both in our galaxy and in the LMC, more clearly illuminating their shared history. – KOREY HAYNES

A quick peek at Deimos

AS IT FLEW BY MARS March 12, the European Space Agency's flagship planetary defense mission Hera snapped pictures of the moon Deimos. The flyby was a gravity assist to the mission's final destination: the binary asteroid system Dimorphos and Didymos. But the mission also took the flyby as an opportunity to test some of its scientific equipment. Hera's vantage point allowed it to survey the little-studied farside of the tidally locked 7.7-mile-wide (12.4 kilometers) moon. This black-and-white image was taken by Hera's Asteroid Framing Camera. Once Hera arrives at its destination, the camera will image the impact crater left in 2022 by NASA's Double Asteroid Redirection Test. – SAMANTHA HILL



ESA

QUICK TAKES

GALACTIC DISCO BALL

The disk of gas and dust surrounding the Milky Way's central black hole lights up with continuous flares, finds JWST in research published Feb. 18. The bursts of light are thought to be analogous in nature to solar flares.

ANCIENT IMPACT

Researchers have discovered what could be Earth's oldest known impact crater, in Western Australia's Pilbara region. The over-60-mile-wide (100 km) feature is an estimated 3.5 billion years old, predating the previous record-holder by 1.3 billion years.

LIFE'S TINY SPARK

A Stanford University team has found that when sprayed, water droplets collide and produce electrical charges that cause "microlightning," which forms organic molecules essential for life. This suggests life could have formed on early Earth through crashing waves, not lighting strikes, as previously proposed.

CHINA'S PLANETARY PLANS

China aims to launch a mission in 2033 to return samples from Venus' atmosphere and send a probe in 2039 to study Neptune and Triton, according to an ambitious roadmap unveiled in March. Other targets include Mars sample return (2028 launch) and Jupiter's moon Callisto (2029 launch).

LONG ROAD HOME

A SpaceX Dragon Freedom capsule returned NASA astronauts Butch Wilmore and Suni Williams to Earth March 18 after 286 days on the International Space Station. The extended stay resulted from issues on last year's test flight of Boeing's Starliner, which returned uncrewed in September.

SNEAK PREVIEW?

A spiral galaxy a billion light-years away has been found sporting radio jets that span 6 million light-years, a feature typically seen only in elliptical galaxies. The finding suggests our Milky Way could develop similar jets, whose radiation could cause mass extinctions on Earth, in the future. – MARK ZASTROW

Strange binary behind long radio signals

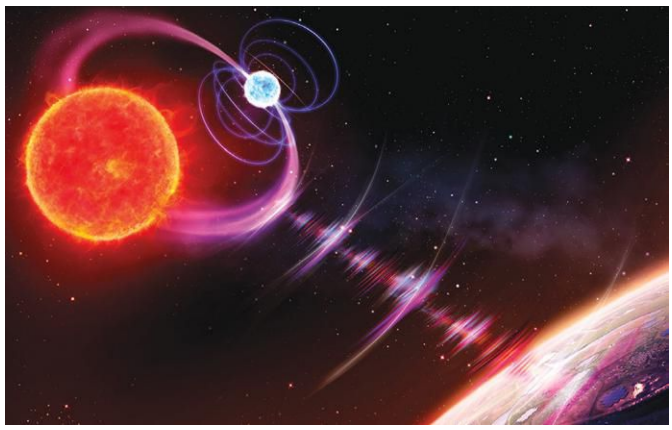
In research published March 12 in *Nature Astronomy*, astronomers identified the source of strange, minute-long radio bursts from deep space. The signals are from a binary system called ILT J1101+5521, which contains a red dwarf star paired with a white dwarf.

The bursts lasted 30 to 90 seconds every two hours, and were identified three years ago in data from the Low-Frequency Array (LOFAR) radio telescope by lead author Iris de Ruiter, then working on her Ph.D. at the University of Amsterdam. (She is now a postdoctoral researcher at the University of Sydney.) De Ruiter and her colleagues suspected something was triggering the bursts. Additional observations identified a binary system containing a red dwarf star and a white dwarf. Red dwarfs are low-mass stars smaller than the Sun; this one is just 0.2 solar mass. White dwarfs are the cores of Sun-like stars, left after the star dies.

"It takes about two hours for the two stars to orbit around each other and every two hours, we see the radio pulse," de Ruiter says. "This strongly leads us to believe that it has to do with some sort of interaction between these two stars."

A binary with a two-hour orbit is unusual. It's likely the stars "started out much farther apart," de Ruiter says. "Then, when the Sun-type star died and became a white dwarf, it started feeding off the red dwarf." That accretion could have caused the stars to move closer, shrinking the orbit.

But astronomers don't see consistent signs of accretion — although, de Ruiter says, those signs could be too faint to pick up.



CLOSE PAIR. Astronomers have traced the source of strange, minute-long radio emission to a binary star system containing a red dwarf and a white dwarf, imagined here beaming their signals to Earth. DANIËLLE FUTSELAAR/ARTSOURCE.NL

The pulses have now gone quiet. De Ruiter says this could be due to several possibilities: Maybe the pulses have truly stopped, or the system is going through a transition, or the signals have grown too faint to detect.

To find out more, astronomers either need the signals to kick on again, or need to identify other similar sources as binary systems. Researchers also plan to study this system in other wavelengths to learn more about its characteristics and history. — JOHN WENZ

FAMILY OF FOUR. An artist's concept imagines how the Barnard's Star system would appear from the surface of one of its four barren, rocky planets. The star itself lies at top center. INTERNATIONAL GEMINI OBSERVATORY/NOIRLAB/NSF/AURA/P. MARENFELD

Planet trio found around Barnard's Star

Barnard's Star, a red dwarf roughly 6 light-years away, is the fourth-closest star to Earth. Yet its first confirmed planet, Barnard b, wasn't found until 2024. Now, three more planets have been confirmed in a paper published March 11 in *The Astrophysical Journal Letters*, bringing the total to four.

The planets were all found using the radial velocity method, which looks for shifts in a star's light caused by the tug of an orbiting planet. The new research was led by a team from the University of Chicago that observed Barnard's Star 112 times using the Gemini North telescope in Hawaii between 2021 and 2023. They were following up on potential signals in data collected by a separate team, which identified Barnard's Star b using the Very Large Telescope in Chile in 2024 and noted three other possible planets. This prompted the UChicago team to examine their data, which helped them confirm Barnard's Star b and led to the discovery of Barnard's Star c, d, and e.

Barnard b is a rocky planet roughly 30 percent Earth's mass, with an orbital period of 3.15 Earth days. The newly found planets are all less massive, with periods between two and seven days.

All four planets orbit too closely to their star for their surfaces to host liquid water. Red dwarfs are also notoriously active, giving off flares and radiation that would make it difficult for the planets to hold on to their atmospheres. Still, the study shows there are plenty more worlds left to find, even close to home. — NICK OAKES

Follow us on
Facebook!

GO TO
www.Facebook.com/AstronomyMagazine

Because telescopes are for one-eyed pirates

BT 127 SD Reviewed: Astronomy TOP 10

OBERWERK Obsessed with Binoculars® oberwerk.com

Fundamentals First Fund

An ETF
Symbol KNOW
Your money
Carefully managed

Abstract

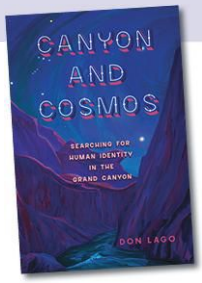
The Fundamentals First Fund, an ETF, is part owner of approximately 100 publicly traded worthy companies, and it owns publicly traded debt. These worldwide companies are vital, important, useful, or just plain nice to have around, and most have been pursuing their business course for decades. We individually select these companies with care and in a manner as to spread our risk so that no single company event can cause more than a bruise. Mason Capital has managed money this way for more than three decades. If you are more specifically interested in who we are, how we do it, and how you might participate, read on.

www.FundamentalsFirstFund.com
(Our Website Has a Lot About Us)

2/21/24 IPO Market Open:	$10.00
3/31/25 Market Close:	$10.52
Dividends Paid:	$ 0.18

Investors should consider the investment objectives, risks, charges and expenses carefully before investing. For a prospectus or summary prospectus with this and other information about the Fund, please call 617-228-5190 or visit our website at www.fundamentalsfirstfund.com
Investments involve risk. Principal loss is possible.
Quasar Distributors LLC.

CANYON AND COSMOS:
SEARCHING FOR HUMAN IDENTITY IN THE GRAND CANYON.
By Don Lago



The Grand Canyon is a powerful Walden Pond for exploring the place of humans in the grand scheme of things.

"Lago links the very fabric of humanity to stories of the Canyon's water below, heavens above, and rocks within, using the Canyon as a portal to understand our place in the universe. This is nature writing at its best!"
--Kevin Schindler, Lowell Observatory historian

https://unpress.nevada.edu/9781647791957/canyon-and-cosmos/

UNIVERSITY OF NEVADA PRESS

COSMIC COLLECTIBLES

Shop high-end astronomy collectibles including verified artifacts, geologic samples, and limited edition tributes to space exploration.

Shop now at TheSpaceStore.com/Collectibles

the space store

Titoonz/Dreamstime.com

HOW WEIRD IS THE MILKY WAY?

By studying what makes the Milky Way unique, astronomers are hoping to understand our galaxy's past and unravel the mystery of dark matter.

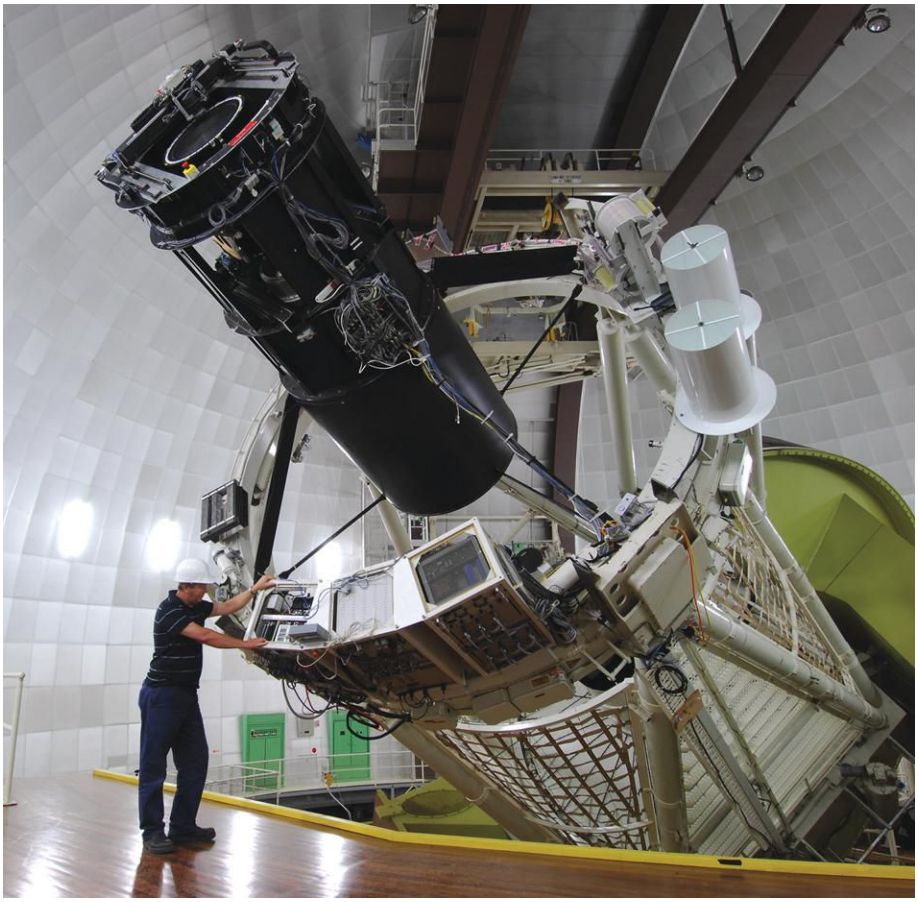
BY SHARMILA KUTHUNUR

IN THE VAST EXPANSE OF THE UNIVERSE, the Milky Way Galaxy holds a special place in our hearts. It is our home, and after studying it for decades from our cosmic residence nestled within one of its majestic spiral arms, we know it better than any other galaxy.

But how truly typical — or extraordinary — is the galaxy that cradles our existence? In other words, to what extent does it share its history with other galaxies scattered across the grand tapestry of the cosmos?

ABOVE: The Milky Way and its two largest satellite galaxies — the Large and Small Magellanic Clouds — lie above the horizon (at left) in this panorama taken from Tivoli, Namibia. PATRICK WINKLER

RIGHT: To determine the distances of hundreds of satellites around Milky Way-like galaxies, the team made use of the 3.9-meter Anglo-Australian Telescope in New South Wales and a spectrograph that was built in the 1990s. ANGLO-AUSTRALIAN TELESCOPE

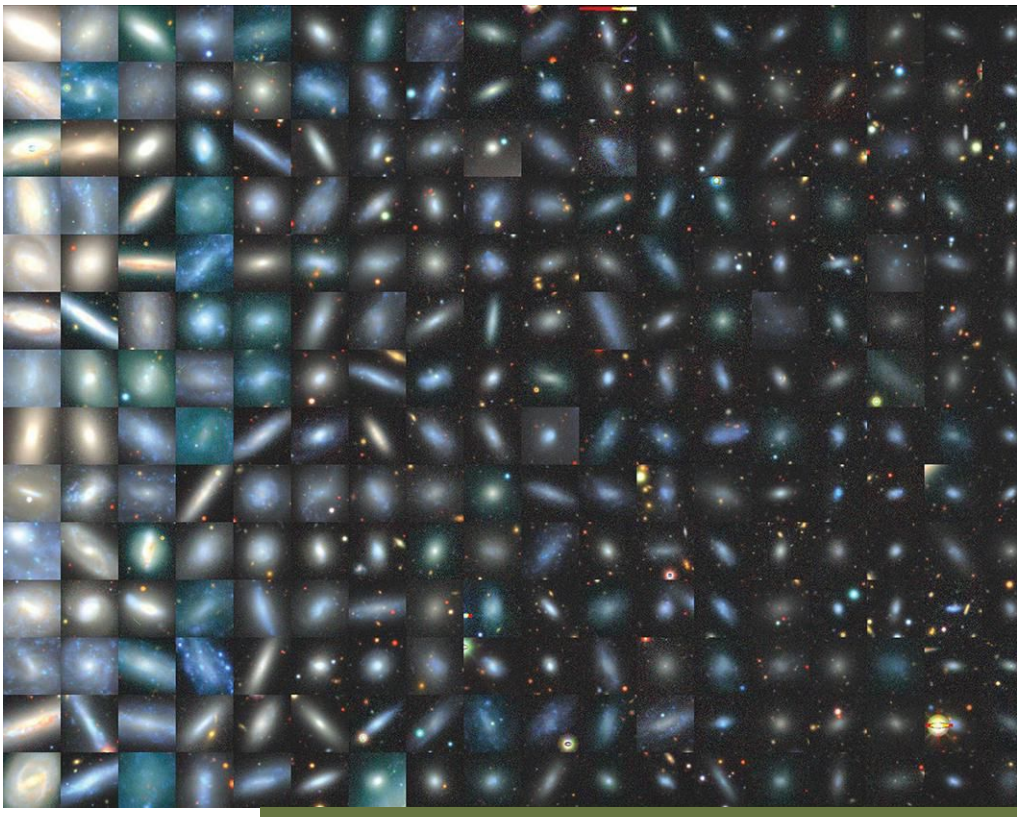


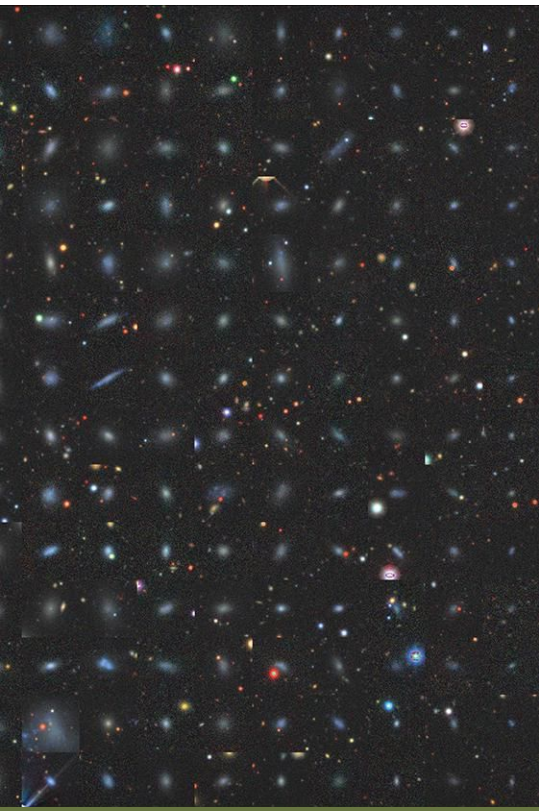
Placing the Milky Way's uniqueness, or lack thereof, in a broader context is crucial because, for decades, scientists have used it as a model to understand how galaxies form and evolve. However, in a universe filled with more galaxies than we've ever been able to count, the Milky Way is just one example. What if we've been misled into thinking some of its traits are actually quirks, when, in reality, they might be typical of most galaxies?

Around 10 years ago, Marla Geha at Yale University and Risa Wechsler at Stanford University launched an ambitious effort to answer this question. Their approach involved looking not only at galaxies themselves, but also their

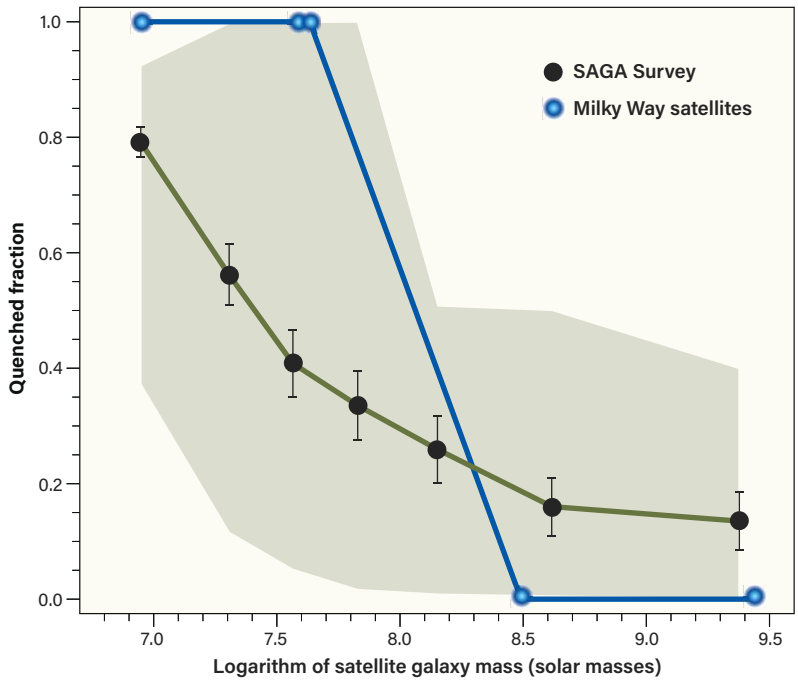
entourages of dwarf galaxies — satellite galaxies that orbit their larger hosts. Because dwarf galaxies are smaller, they are more sensitive to their environment and can act as probes. Studying them can yield insights into their host galaxies' invisible halos of dark matter and how they evolved.

Geha and Wechsler named their project the SAGA (short for Satellites Around Galactic Analogs) Survey and began the herculean effort of cataloging dwarf galaxies in the distant universe one at a time, focusing on the ones that orbit galaxies known to be similar to the Milky Way. But the faint, diffuse nature of dwarf galaxies made identifying them — and distinguishing them from background galaxies — challenging, meticulous work. By 2017, the team had studied only eight Milky Way analogues. "We knew it was a little bit crazy," says Geha. "The idea was this would be a long, slow process but that it was so worth the challenge of doing it."





SATELLITE STELLAR BIRTH RATES



ABOVE: All 378 of the satellite galaxies cataloged by the SAGA Survey over the past decade — belonging to 101 Milky Way-like galaxies — are pictured in this mosaic. YAO-YUAN MAO/UNIVERSITY OF UTAH/DESI LEGACY SURVEY SKY VIEWER

LOWER LEFT: The Magellanic Clouds hang over the Atacama Desert in Chile, next to the arch of the Milky Way in this photograph. Studying satellite galaxies can yield insight into their host galaxies, their dark matter halos, and their surrounding environments. MATT DIETERICH

TOP RIGHT: The SAGA team's analysis of its survey showed that small satellite galaxies are more likely to be quenched and larger satellite galaxies are more likely to be forming stars. The Milky Way follows this trend, but to an extreme degree: Only its two largest satellites — the Magellanic Clouds — are forming stars, and every satellite smaller than the Small Magellanic Cloud is quenched. GEHA ET AL. HTTPS://DOI.ORG/10.3847/1538-4357/AD61E7 (CC BY 4.0)

The decade-long effort has now mapped 101 Milky Way analogues in the distant universe, and 378 of their respective satellites. The team's results suggest that while our galaxy is far from a cosmic anomaly, its satellite galaxies do sport distinct traits that make the Milky Way something of an outlier compared to its peers.

The quest for context

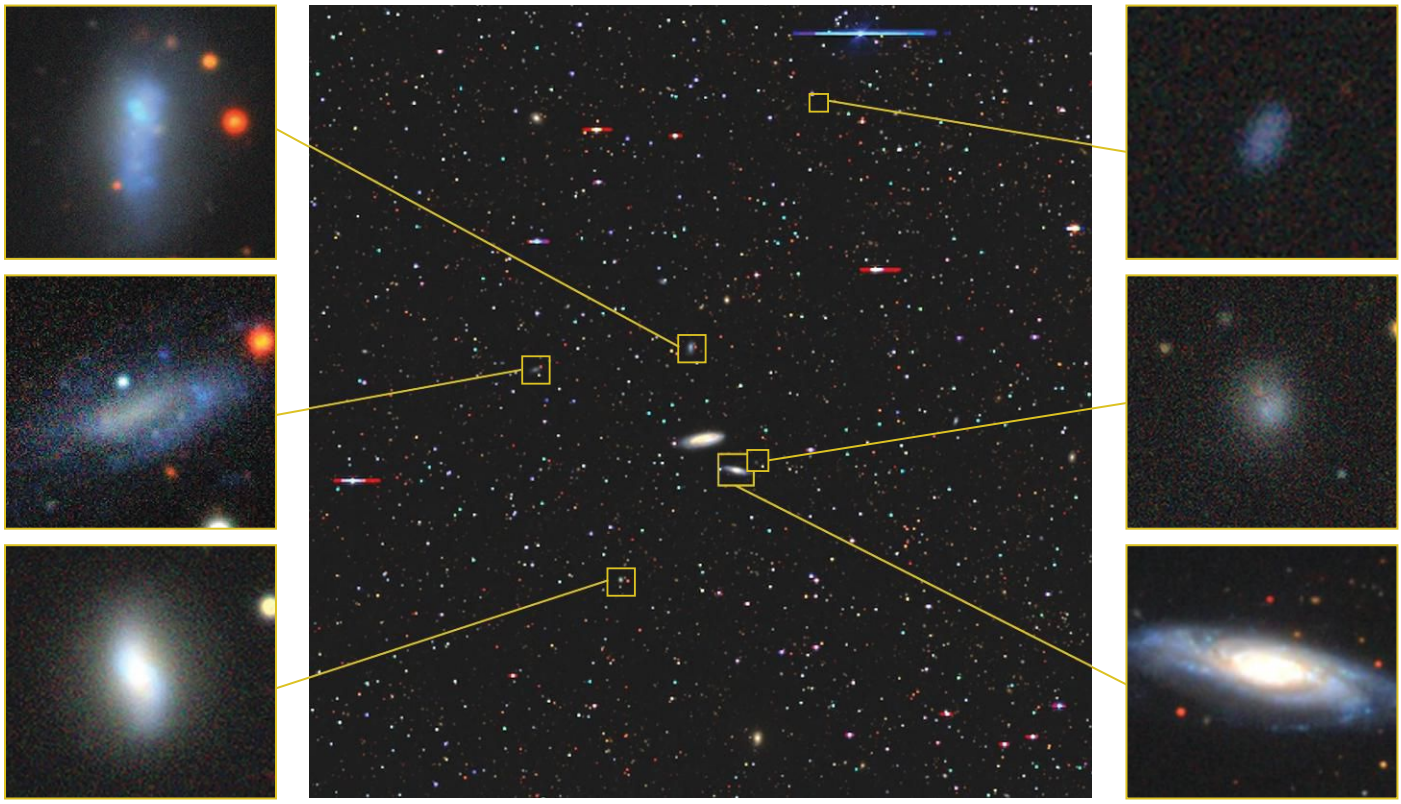
Most of what we know about tiny, faint satellite galaxies comes from studying those around the Milky Way. Our galaxy's most famous examples are the Large Magellanic Cloud (LMC) and the Small Magellanic Cloud (SMC), which lie around 160,000 light-years and 200,000 light-years away, respectively, in the southern sky. Both of them contain numerous hotspots of star formation, like the Tarantula Nebula in the LMC. But the Milky Way also counts upward of 50 smaller dwarf galaxies as satellites, none of which are making any stars.

When scientists attempt to re-create Milky Way-like systems in computer simulations, even the best models struggle to perfectly replicate this swarm of dwarf galaxies orbiting our galaxy. This has led astronomers to worry whether the Milky Way — their primary benchmark — accurately captures the broader population of galaxies and their faint satellite galaxies.

"This has been a big challenge in the field for decades," says Andrew Wetzel of University of California, Davis, who was not involved with SAGA. "If I have a small sample, is it representative of the population as a whole?" By cataloging hundreds of Milky Way-like systems beyond our cosmic neighborhood, SAGA has begun to provide that much-needed statistical context, he says.

A key part of this effort is that, over the past decade, the SAGA team has become increasingly efficient at the challenging task of distinguishing satellite galaxies from a vast backdrop of more distant galaxies, says Yao-Yuan Mao of the University of Utah, who simulates Milky Way-mass satellite systems for SAGA telescope observations. And that improvement has benefited from advances in technology. As one example, Mao says it took him about a year to run simulations of 45 Milky Way analogues in 2015, but the same task took only a week last year. "The computational power has increased dramatically," he says.

The survey's first significant result, published in 2017, reported satellite galaxy populations around just eight Milky Way analogues. But already, the team was beginning to see that our galaxy and its collection of satellite galaxies was not typical of other galaxies in the sample. With the exception of the Magellanic Clouds, the Milky Way's dwarf satellites have all stopped forming stars for a billion years or more — a state that astronomers call quenched. But of the 27 dwarf galaxies the SAGA team identified



orbiting other galaxies, all but one were still actively forming stars.

By 2021, the SAGA collection of host galaxies had grown to 36, and the trend continued. In 2024, the team published their most recent results in *The Astrophysical Journal*, bringing their count to just over 100 host galaxies.

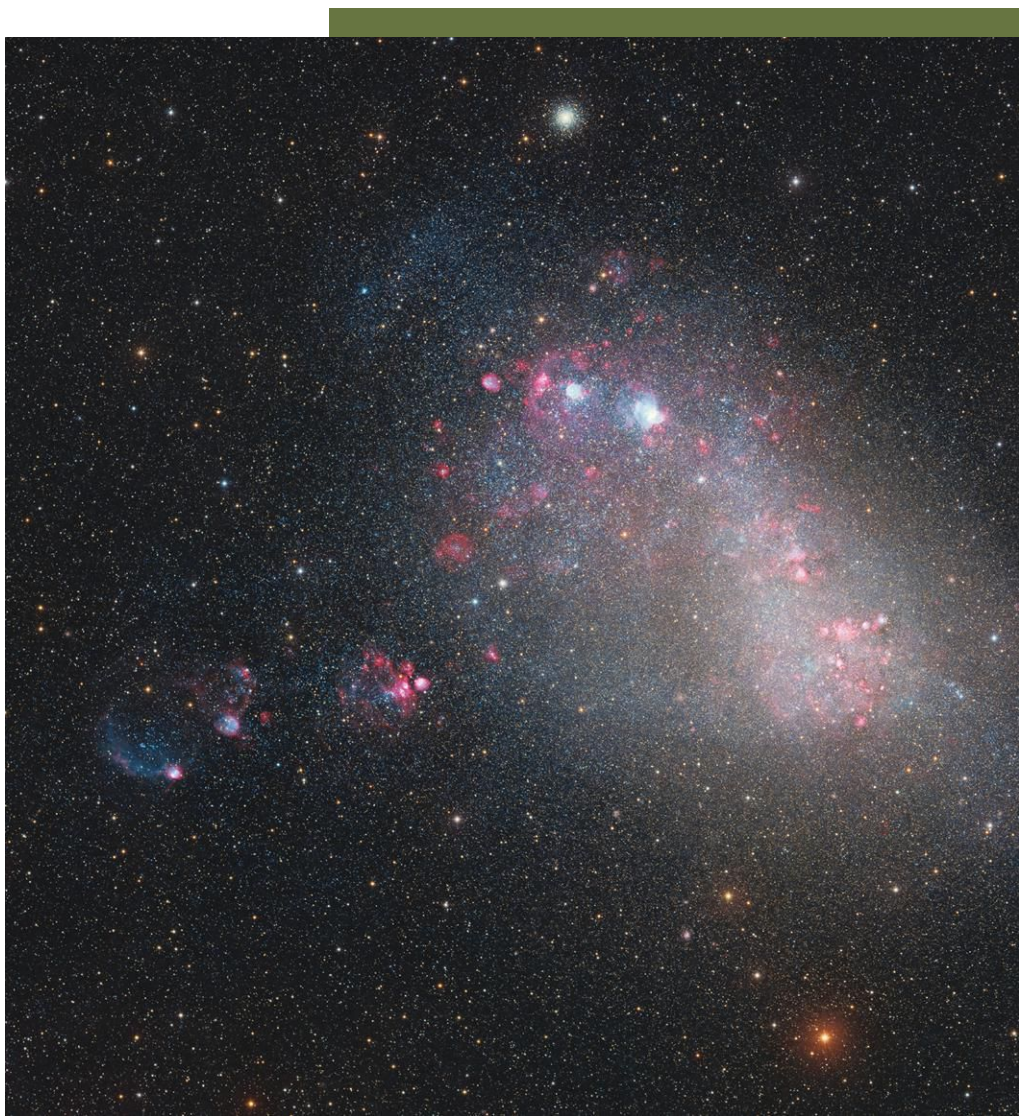
These results show that our galaxy's mix of satellites is relatively uncommon. The Milky Way's swarm of dead, quenched dwarf galaxies stands in stark contrast to satellites of Milky Way-like galaxies in the distant universe, most of which are still birthing new stars.

What's more, the sample is now large enough for the team to analyze statistical trends — for instance, how a more massive satellite galaxy is more likely to be forming stars.

For theorists like Wetzel, this growing dataset is valuable for fine-tuning computer simulations in ways "we'd never be able to do" using just the Milky Way, he says. "I've been a big fan of what the SAGA team has done — it has been a tremendous contribution to the field."

Recent acquisitions

So how can we explain the Milky Way's flotilla of satellites? The likeliest



explanation, says the SAGA team, is that while the quenched majority of satellite galaxies are older, the star-forming Magellanic Clouds are new arrivals to the Milky Way's sphere of influence. Based on measurements of their orbits, astronomers are confident that these galaxies have only recently fallen into our galaxy's halo — the vast cloud of invisible dark matter that encompasses our galaxy — perhaps in the last 1 billion years.

"They haven't had a chance for their star formation to be shut down," says Ethan Nadler of the University of California, San Diego, who co-authored recent SAGA papers.

Now that the Magellanic Clouds have fallen under the Milky Way's sway, the larger host is eroding the ability of its satellites to form stars. Indeed, if your eyes could observe these satellite galaxies in radio wavelengths, you would see that gas — the raw material needed for forming stars — is gradually being stripped away by our galaxy's immense gravitational pull. Models of this interaction suggest that in about 2 billion years, after just another orbit or so around the Milky Way, the Magellanic Clouds will have lost most, if not all, of their gas, essentially shutting down their ability to form new stars.

"It's a very interesting result," says astrophysicist James Bullock of the University of California, Irvine, who was not involved with SAGA. Rather than simply being dictated by the mass of the satellite galaxy, this finding suggests that the complex process of stripping a satellite's gas and quenching star formation is more intricate and prolonged, he says. "Maybe that's not surprising, but it's good to know."

Possibly, the Milky Way is peculiar in that it acquired most of its satellites earlier in its history than similar galaxies. This early accretion gave the Milky Way more time to quench its satellites by stripping away their star-forming gas, leaving only a few later additions like the LMC and SMC, which have not yet had their star formation shut down. Meanwhile, the expelled star-forming gas eventually became part of the Milky Way's halo, fueling it and helping it grow.

Another unique factor in the evolution of the Milky Way and its satellites could be that our galaxy has a close neighbor, the Andromeda Galaxy (M31). These two major galaxies could be influencing each other's satellite systems in ways that set them apart from other host galaxies in the SAGA survey, says Nadler.

"I think we now genuinely understand some of the [Milky Way's] quirks in ways that we just didn't before," says Geha. Mao adds that "it is not quite common that you learn something new and concrete about the universe in your lifetime — this is quite cool."

Shining light on dark matter

Low-mass satellite galaxies, like those being cataloged by SAGA, are not only markers of an individual host galaxy's history. They may also hold great potential for probing one of the broadest open questions in cosmology — the elusive nature of dark matter. This substance makes up 80 percent of the universe's mass, but its nature remains a mystery and decades of efforts to detect proposed dark-matter particles have been unsuccessful.

From observations of millions of galaxies and the expansion of the universe itself, scientists have complementary ways of indirectly measuring dark matter's effects on large scales, primarily through its gravitational influence. "But we need the most help at smaller scales," says cosmologist Dillon Brout at Boston University, who was not directly involved with SAGA.

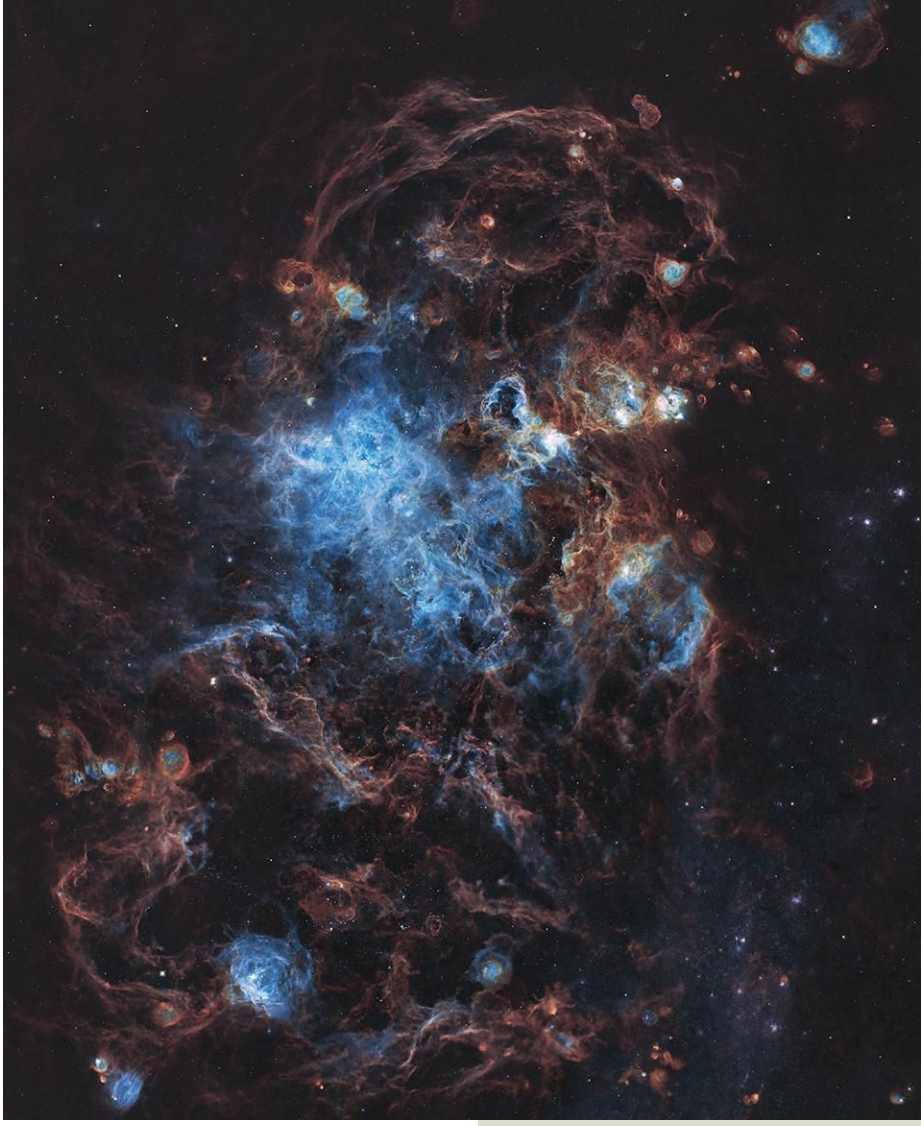
SAGA's approach to counting quenched satellite galaxies allows cosmologists to constrain the nature of dark matter and distinguish between competing models, as each is expected to leave specific signatures on the distribution of satellite galaxies.

For instance, in the cold dark matter model, the particles that make up dark matter travel at speeds much less than that of light. This type of theorized dark matter is predicted to clump together more easily, which would result in a

LEFT: Advances in technology enabled the SAGA team to identify small, faint dwarf galaxies orbiting larger galaxies similar to ours. This Milky Way analogue, NGC 7541, has six small satellites cataloged by the SAGA survey. YASMEEN ASALI/YALE UNIVERSITY/DESI LEGACY SURVEY SKY VIEWER

BELOW: The Small Magellanic Cloud teems with regions of star formation, visible as red pockets where young stars are heating and ionizing hydrogen gas. TEAM SHARA

BELOW RIGHT: Leo I, located near the star Regulus, is a faint satellite galaxy of the Milky Way, and one of the least luminous in the SAGA survey. A 2021 study found that it experienced a major episode of star formation a billion years ago, when it made its closest pass to the Milky Way's center. This incursion into the heart of the Milky Way stripped it of much of its gas, rendering it unable to effectively form stars and leaving it substantially quenched. KFIR SIMON



The Tarantula Nebula in the Large Magellanic Cloud is an enormous stellar factory over 1,000 light-years wide. VIKAS CHANDER

greater number of satellite galaxies. Alternatively, warm dark matter travels faster and acts like a Mixmaster of sorts, smoothing out the early universe so that it forms fewer dark matter halos and thus fewer satellite galaxies.

Cosmologists are preparing to perform detailed tests on the particle nature of dark matter using the SAGA survey results, Brout says. "Ten or 20 years ago, something like this would have been unthinkable."

The wealth of information provided by SAGA is also enabling cosmologists to probe key questions such as how long it takes for a satellite galaxy to cease forming stars, and how close it must be to the center of its host galaxy before this happens, adds Bullock.

Observations of any individual galaxy essentially capture a snapshot in time, so by measuring the distribution of satellites in Milky Way analogues at varying distances, cosmologists can begin to string together a timeline and test whether a single dark-matter model can explain satellite galaxies in both the early universe and the nearby universe.

"That's a big story to tell and if we can tell it with one underlying model of dark matter, that's a huge win," says Brout.

The road ahead

Notably, SAGA's core team has remained intact over the past decade, even though two of their largest observing runs occurred during the challenging COVID-19 pandemic. "It's a very small team given the scope of what we did," says Geha, and a tight-knit one.

She recalls setting up six computer screens in one corner of her living room to continue gathering remote observations from the telescope the team was using in Australia, while her son occupied another corner for his kindergarten classes. The SAGA team's weekly check-ins provided much-needed support during the tough times and "did a little more than just science," she says.

For all the groundbreaking work the SAGA team members accomplished, they relied on relatively humble tools, using the venerable 6.5-meter MMT Observatory in Arizona and the 3.9-meter Anglo-Australian Telescope in New South Wales. The latter employs an old spectrograph that has been on the telescope for more than two decades.

"We were basically using the Honda Accords of instrumentation — nothing fancy," says Geha. "The innovation was asking a different question than people had asked in the past."

For now, the SAGA team has paused further observations and plans to focus on deepening their understanding of the systems already cataloged. At this point, doubling or tripling the number of Milky Way analogues — which could take a decade — doesn't actually teach a whole lot more, says Geha. To be truly revolutionary, the number of analogues would need to increase by at least a factor of 10, a feat that will require next-generation technology.

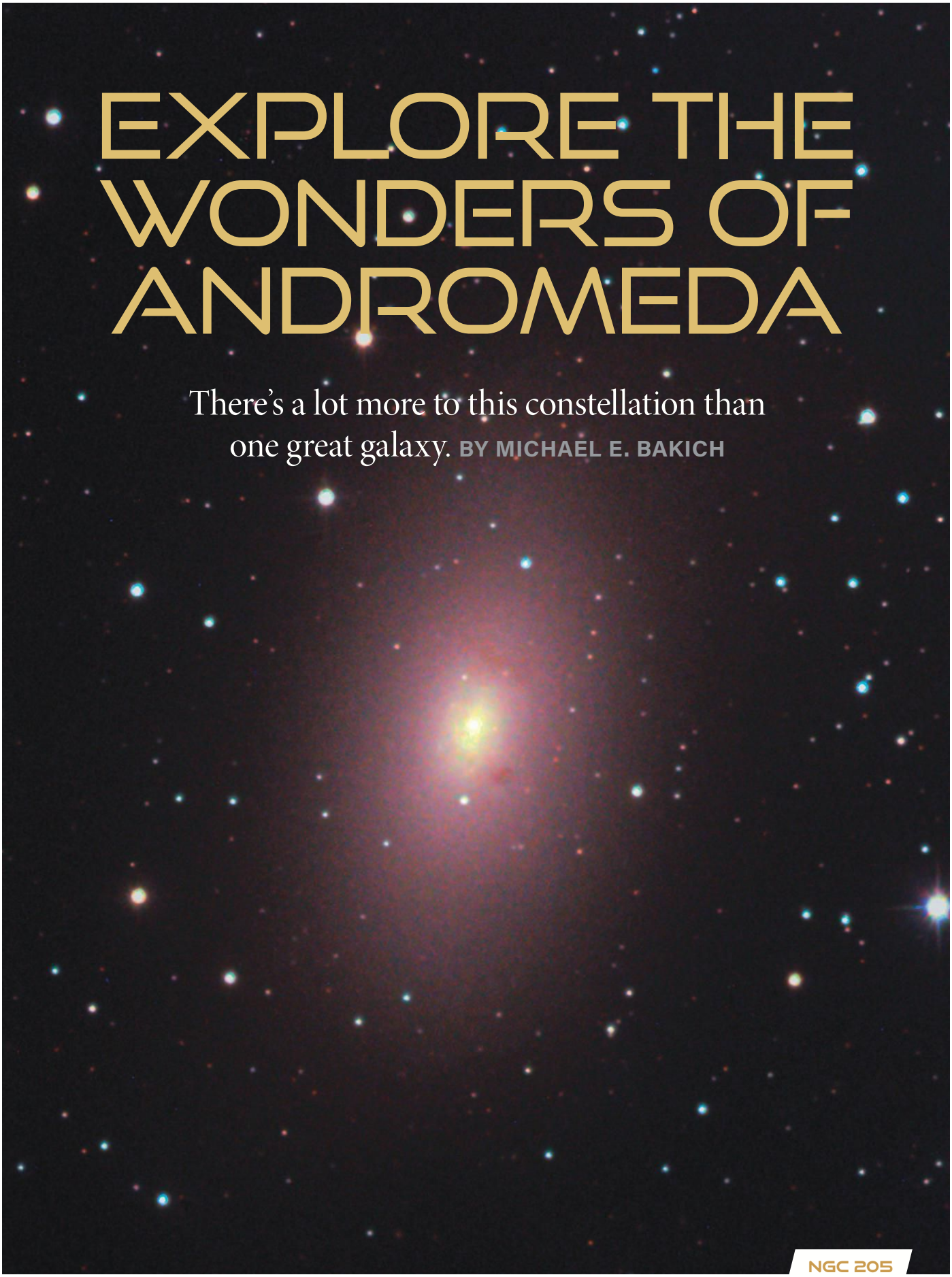
That leap will arrive when the Vera C. Rubin Observatory begins operations later this year. Designed to image nearly the entire southern sky once every three nights, Rubin will catalog thousands of ultra-faint small satellites all the way to 10 billion light-years across the universe. And NASA's upcoming Roman Space Telescope is expected to image stellar streams of satellite galaxies in further detail, allowing astronomers to infer how far along the quenching process each galaxy is. Together, the two efforts seem destined to publish a firehose of data that will revolutionize the study of galaxy evolution and dark matter.

Like the SAGA team, these works will help astronomers better appreciate the Milky Way — not only as our beloved home, but also as part of a much broader cosmic landscape.

Sharmila Kuthunur *is a Seattle-based science journalist covering astronomy and space exploration. She earned a master's in journalism from Northeastern University.*

EXPLORE THE WONDERS OF ANDROMEDA

There's a lot more to this constellation than one great galaxy. BY MICHAEL E. BAKICH



NGC 205

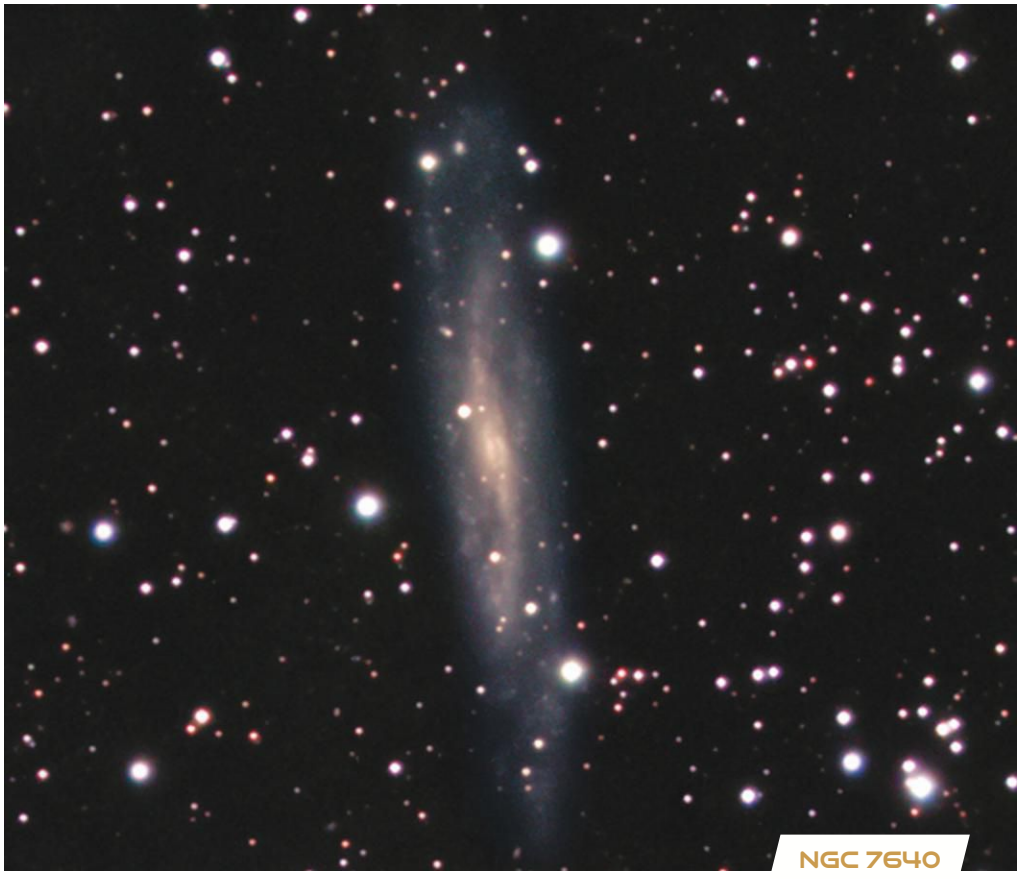
GERALD RHEMANN

THE BLUE SNOWBALL (NGC 7662)

DEREK SANTIAGO

M32

ADAM BLOCK



NGC 7640

The constellation Andromeda the Princess is part of the largest mythologically connected group in the sky. Her parents are Cepheus the King and Cassiopeia the Queen. Perseus the Hero saved her from being sacrificed to Cetus the Whale (a sea monster in the tale). And Pegasus the Winged Horse was born when Perseus cut off the Gorgon Medusa's head.

Andromeda is best viewed in the early evening during the first two weeks of October when — from our perspective — it lies across the sky from the Sun. It's invisible around early April when it lines up with our daytime star.

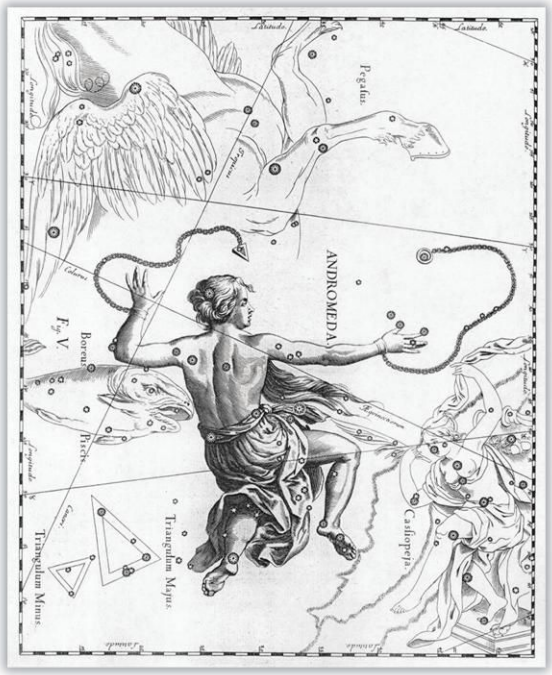
NGC 7686

THE ANDROMEDA GALAXY (M31)

LEFT: BERNHARD HUBL; RIGHT: TONY HALLAS

The Princess is above average in size, ranking 19th among the 88 constellations, and near the middle (37th) in overall brightness. Interestingly, its brightest star, Alpheratz (Alpha [α] Andromedae), has been an official part of the figure only since 1922. Before then, it was also designated Delta (δ) Pegasi, and, indeed, it's still the brightest of the four stars in the asterism called the Great Square of Pegasus.

As is my habit when I describe objects within a constellation, I start with the ones farthest west and move eastward so each subsequent object will rise higher as the evening progresses.



After Princess Andromeda was saved by the hero Perseus and lived out the rest of her days, the goddess Athena placed her forever amongst the stars as a way to honor her. WIKIMEDIA COMMONS

Feast your eyes

We'll start our observing session with a bit of a tough one. It's barred spiral galaxy **NGC 7640**, which glows at magnitude 11.3. As if that weren't faint enough, it's one of those "slender slivers" in the sky, measuring 10' by 2.2'.

To find it, point your telescope 4° east-southeast of Omicron (ο) Andromedae. You'll see its main features — an elongated core and two really faint arms — through an 8-inch telescope. An 11-inch scope will reveal subtle extensions to the north and south. This galaxy contains some big star-forming regions near the core, which make it look unevenly lit.

Once you've checked that tough catch off the list, it's time to enjoy the **Blue Snowball** (NGC 7662). This planetary nebula also is number 22 in Patrick Moore's Caldwell Catalog. It glows at magnitude 8.3 and has an oval shape that measures 12" by 18". Look for it not quite 2½° west-southwest of Iota (ι) Andromedae.

I've had fun comparing what I detect as the color of this object with other observers. Some see it as light blue, turquoise, a bit more white than blue, and differing hues of light green. The cool thing is that we're all right, at least in our own minds, because human eyes vary slightly in their sense of color perception. Does this object warrant its common name based on your eyes?

An 8-inch scope with an eyepiece that gives a magnification of 200x or more will reveal a ring of gas around the Snowball's hollow center. There's a 13th-magnitude central star in there, but you'll need a much bigger scope to spot it. Look closer and see if you can see the faint gas shell that surrounds the ring.

Next up is an open cluster that sharp-eyed observers can spot with their naked eyes from a dark observing site. It's **NGC 7686**, which glows at magnitude 5.6 and measures a worthy 15' across — half the diameter of the Full Moon.

To find it, aim your telescope 3° north-northwest of Lambda (λ) Andromedae. Some observers report that the cluster has a triangular appearance, but that depends on the magnification you're using. Low powers show that figure best. Medium-size telescopes reveal about two dozen stars, two of which are brighter than the rest. Larger instruments will triple that number, but all of those stars are quite faint.

CHUCK DOMARACKI

Now we come to **NGC 205** and **M32**, two of the sky's classic dwarf elliptical galaxies. They're bright and super easy to find: Just locate the Andromeda Galaxy (M31). Any telescope will show NGC 205 and M32 as satellites of that celestial wonder.

Both galaxies glow around 8th magnitude, but NGC 205 appears three times bigger. It measures 19.5' by 12.5', while M32 measures "only" 11' by 7.3'. That's still about 11 percent of the area the Full Moon covers. Neither of these galaxies shows any details no matter what scope you point at them, so give them a quick look and let's turn our attention to the object you're reading this story for.

The **Andromeda Galaxy** is the only such object named for its constellation. Visible to the naked eye — and looking like a piece of the Milky Way that broke off — from even moderately dark sites, this object also goes by the designations M31, NGC 224, HD 3969, UGC 454, and lots more. It's famous for many reasons, but observers value it as the showpiece celestial object of the northern sky. Indeed, with a magnitude of 3.4, only the Large and Small Magellanic Clouds are brighter than M31.

The Andromeda Galaxy is a giant. It covers 185' by 75'. That length is roughly the same as six Full Moons side by side, and its area is greater than 18 Full Moons. Because it is so big, you can approach studying it in one of two ways.

If you have access to 15x or 20x binoculars, start by looking at the entire galaxy. First, note the true field of view of your binoculars, a number usually printed on them. Then determine how much of M31's length you can see by counting how many fields it takes to take it all in. Second, identify M32 and NGC 205, which are right next to their big brother. Third, compare those two galaxies to M31's nucleus, which resembles an elliptical galaxy. Finally, find the dark lanes — made primarily of dust — along the spiral arms.

The other way to observe the Andromeda Galaxy is by cranking up the power and examining small parts of it through your telescope. An 11-inch or larger scope works best. Look for several star-forming regions within M31's spiral arms.

Next on our list is an elliptical galaxy called **Mirach's Ghost**, also known as NGC 404. The common name comes from the fact that the Ghost lies a mere 7' from Mirach (Beta [β] Andromedae), a star of magnitude 2.1. It glows at magnitude 10.1 and has a diameter of 6'. That makes Mirach 1,738 times as bright as its Ghost, and that makes NGC 404 a little tough to see.

But tough doesn't mean impossible. In an 8-inch scope, insert an eyepiece that gives a magnification around 200x. Then just nudge the star out of the field of view. You'll see a circular patch of light with a brighter center and — as with

NGC 752

ANTHONY AYIOMAMITIS

most ellipticals — no detail. It is, however, fun to show people this object.

Our next object, open cluster **NGC 752**, lies closer to Beta Trianguli (not quite 4° northwest of it) than to Beta Andromedae. Most sharp-eyed observers can spot it without optical aid from a dark site. It shines at magnitude 5.7 and spans an impressive 50′.

Because it's so big and bright, you should be able to spot some 30 stars through 10x binoculars. Through a telescope, if you keep the magnification below 50x, that number will jump to 100. Note the zigzag line of four stars that runs east to west through the center of NGC 752.

Now we come to the only double star on our list, **Almach** (Gamma [γ] Andromedae), and it's a nice one. Although it appears as a single star to our eyes, pretty much any telescope will split the pair into yellow Gamma^1 (γ^1), which glows at magnitude 2.3, and blue Gamma^2 (γ^2), which glows at magnitude 5.0. The separation between the pair is 9.8″.

Just a note that if you have access to an 11-inch or larger scope, you might try to split Gamma^2, as it is a binary as well. Its two stars are much closer — a mere 0.4″ apart, and their magnitudes are nearly identical: 5.1 and 6.3.

Next up is one of my favorite galaxies, but I'm partial to edge-on spirals. Yes, I know M31 is technically edge-on, but the **Silver Sliver** (NGC 891), also known as Caldwell 23, inclines a mere 1.4° to our line of sight. To find it, start at Almach and head 3½° east.

The Sliver glows at magnitude 10 and got its common name because it's four times as long as it is wide, measuring 13′ by 2.8′. Because it is so slender, it looks best through 11-inch and larger telescopes.

At low power, the field of view contains dozens of Milky Way stars that lie a lot closer to us than to NGC 891. The galaxy's slight central bulge is also evident at low powers, but you'll want to crank the magnification past 200x to examine the dust lane that divides the galaxy lengthwise into two parts.

Our final object is **NGC 956**, which was originally classified as an open cluster, but astronomers now consider an asterism — a chance alignment of stars. In fact, the two brightest stars in the cluster, which lie at its northern and southern edges, are much closer to us than the rest of the ones we can see. NGC 956 lies 5.7° east-northeast of Almach. It glows at magnitude 8.9 and has a diameter of 6′.

As you can see, Andromeda has a lot more going for it than just its namesake galaxy. Head out one night soon and enjoy its wonders. Good luck!

Michael E. Bakich *is an associate editor of* Astronomy *who loves to spend an evening exploring a single constellation.*

NGC 956

MARTIN C. GERMANO

ALMACH (GAMMA [γ] ANDROMEDAE)

JEREMY PEREZ

THE SILVER SLIVER (NGC 891)

TONY HALLAS

Observe THE MULTIHUED SKY

Patience with your eye and telescope will reveal stars of a different color. BY RAYMOND SHUBINSKI

ABOVE: In the summer sky, the constellation Sagittarius the Archer contains lots of colorful stars. BILL AND SALLY FLETCHER

Professional and amateur astronomers post amazing photos of the sky. A colorful, star-filled Milky Way is often shown rising above a landscape, and photos from the Hubble Space Telescope reveal amazing and vivid colors in galaxies and nebulae.

As beautiful as these pictures are, they also can be misleading because they don't truly represent what the night sky looks like to the naked eye. The sky is filled with color, but it is subtle and takes effort to perceive. The human eye is an amazing organ — but it has limitations and can't record the saturated colors that cameras capture using long exposures.

But there is one place celestial color is easy for our eyes to tease out: in the stars. Although a casual observer might think that all stars are white, they actually come in an array of yellow, red, white, and blue hues.

Eyes on the universe

Packed into our eyes are hundreds of millions of photoreceptors called cones and rods. The cones are sensitive to red, blue, and green. Green is the color that the eye is most receptive to in bright light.

In the dark, the rods take over. Millions more of these highly sensitive receptors exist than their brethren, the cones. Rods, however, don't distinguish colors, but are sensitive to low light and therefore allow us to see in dark conditions. So, in

darkness, the rods take over and we lose most of our bright-light perception, making it more difficult to distinguish colors.

Vega and friends

You can test your color acuity on a variety of bright stars. Start with one that appears prominently each summer night: Vega (Alpha [α] Lyrae) is currently high in the sky.

This is an amazing star and offers a wonderful way to start your color journey. For one thing, the star glows at almost exactly 0 on the magnitude scale. For decades, this brilliant luminary was used as a standard reference star for photometric calibrations. On a summer night in 1850, Vega became the first star other than the Sun to be captured photographically. In another first, two decades later, American astronomer Henry Draper captured Vega's spectrum on a glass plate. And if you are willing to wait about 14,000 years, Vega will become the Northern Hemisphere pole star, displacing Polaris.

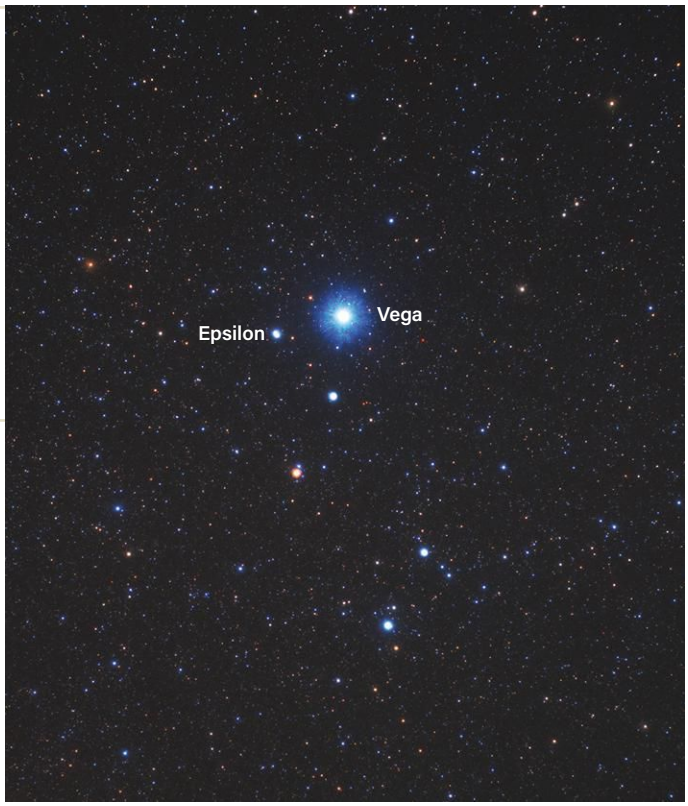
Due to its brilliant white color, Vega is referred to as a beautiful diamond and even "the Arc-light of the sky." Sharp-eyed observers might detect a tinge of blue in Vega, a color that is easier to see through a telescope. Take Vega a bit out of focus and the blue will become more apparent.

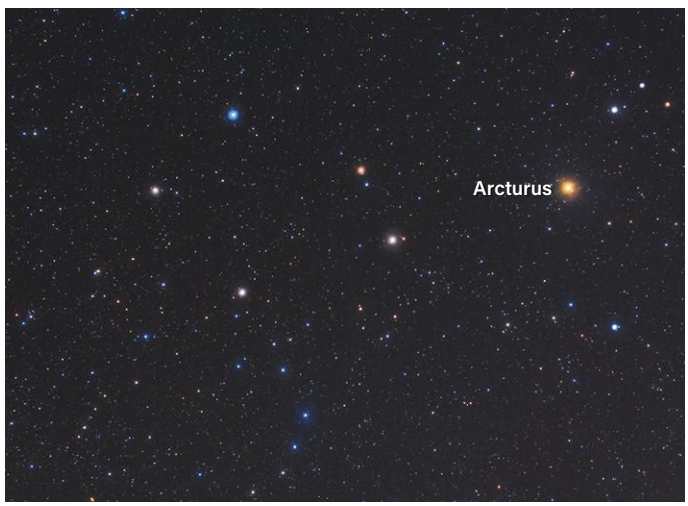
Not far from Vega is a real color challenge. At magnitude 4.7, Epsilon (ε) Lyrae is near the limit of naked-eye visibility under all but the darkest skies. Known as the Double Double, the star splits into two pairs of binary stars through even a small telescope. Victorian astronomers loved recording the delicate colors of stars; one astronomer recorded these pairs as greenish-white and bluish-white, while an English observer claimed to see yellow and red in them. Whether these descriptions were imaginative or real is still debated.

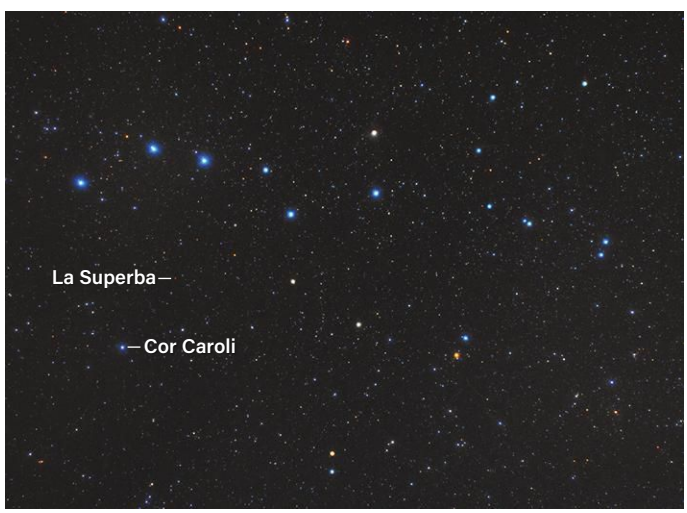
TOP TO BOTTOM: Start looking for star colors by targeting Vega and the Double Double (Epsilon Lyrae) in the constellation Lyra the Harp. TONY HALLAS

Arcturus in the constellation Boötes the Herdsman is decidedly orange. Or do you see it as yellow? TONY HALLAS

Cor Caroli in the constellation Canes Venatici is a double star that offers a nice color contrast, but the real gem here is ultra-red La Superba (Y CVn). TONY HALLAS



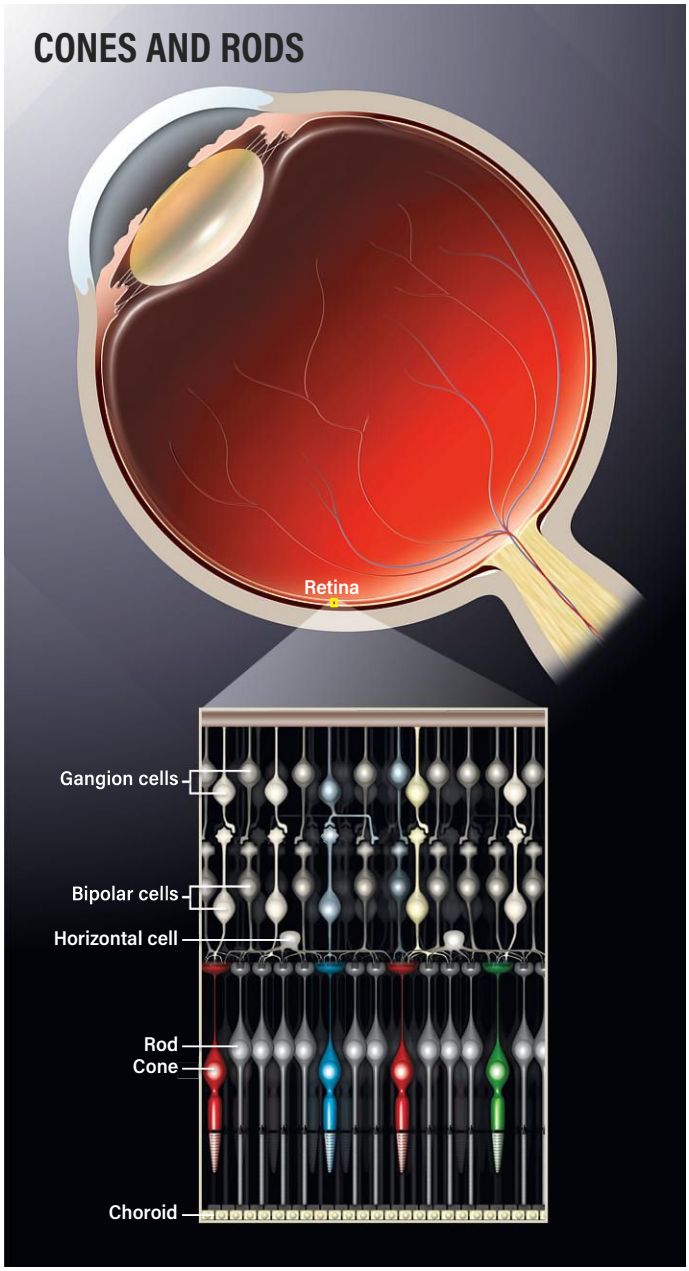




Arcturus

The summer sky is also graced by the beautiful star Arcturus (Alpha Boötis). This star slightly outshines Vega as the fourth-brightest star in the nighttime sky and the brightest sun north of the celestial equator. The ancient astronomer Ptolemy called it "slightly red." Since then, its color has been described as warm amber, yellow, ruddy red, and orange.

The indefatigable astronomy popularizer Garrett P. Serviss wrote, "When [Arcturus] has not risen far above the horizon, [it] is a yellowish red, but when the star is near the mid-heaven the color fades to light yellow." This color change is likely explained by Arcturus shining through an ever-thinner atmosphere as it rises. In 1852, an astronomer claimed that Arcturus "nearly lost its color!" And on the night of Oct. 5, 1858, the ruddy color of Arcturus was ever-so-slightly dimmed when the densest part of Comet Donati's tail passed in front of it. What a sight that must have been.



Our Sun is classified as a yellow-white G-type star, while Arcturus is a K-type star 25 times the size of the Sun. Arcturus is aging and moving into the red giant stage of stellar evolution, which creates its orange hue. The orange glow of Arcturus falling onto a photocell turned on the lights for the opening of the 1933 Chicago World's Fair.

Stars of the dogs

Not far from Arcturus is the small constellation Canes Venatici the Hunting Dogs. The brightest star in this constellation is Cor Caroli, which was named for King Charles II of England. This is a wide double star. The colors have been described as light yellow and blue, pale olive and blue, and even pale copper. Like most observers, however, the great English astronomer John Herschel only saw two white stars. What colors do you see?

The real prize in this constellation is the extravagantly named star La Superba (Y Canum Venaticorum). It glows at magnitude 4.8 and is intensely ruby red. The Jesuit astronomer Angelo Secchi applied the name in 1860 while studying this star's carbon-rich spectrum. The prevalence of carbon in the star's atmosphere absorbs blue light and creates its red color. To further enhance the color, view La Superba with a small telescope at low power, slightly out of focus.

The Scorpion's prizes

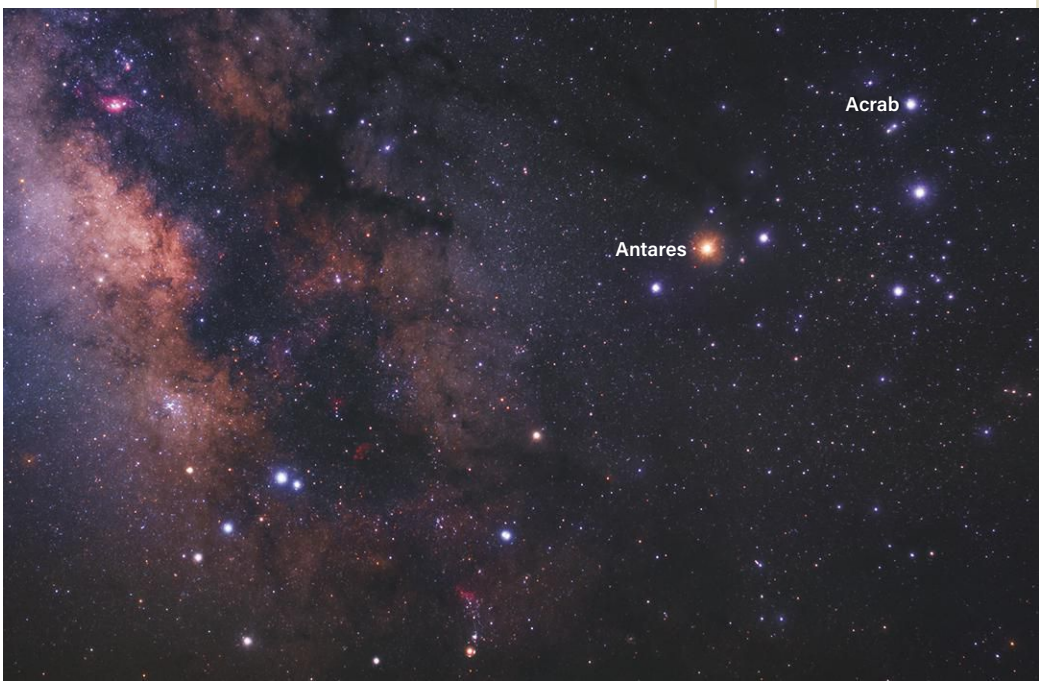
Low in the southern summer sky is the star known as "the rival of Mars": Antares (Alpha Scorpii). The brilliant red of Antares stands out among the blues and whites of the surrounding stars in Scorpius. Antares is part of an expanding cluster of massive stars. This puffed-up giant of a star has a surface temperature of about 5,500 degrees Fahrenheit (3,040 degrees Celsius), which is about half as hot as the Sun.

At nearly 12 billion years old, Antares has evolved into a red supergiant star. Even if you have trouble seeing some star colors, as I do, Antares is an easy exception. Through a medium-size telescope, Antares resolves into a beautiful binary system. The fainter companion is a hot star that appears bluish to most observers. Some have even described this star as purple or green. The star's color is further enhanced because of the contrast with ruddy Antares.

Not far from Antares is the upper claw of Scorpius, marked by Acrab (Beta [β] Scorpii). With modest telescopic magnification, Acrab

LEFT: The eyes' cones let us see colors, while rods help us see in the dark. *ASTRONOMY*: ROEN KELLY

BELOW: Pretty much every observer sees Antares in Scorpius as red, but when you split Acrab, do you see this double star as white and blue or yellow and green? TONY HALLAS



splits into two beautiful stars. Here lies another color challenge: To most observers, the primary star appears white and the fainter star pops out as distinctly blue. Others have claimed to see pale yellow and green. Whatever you may perceive, Acrab is intense and colorful.

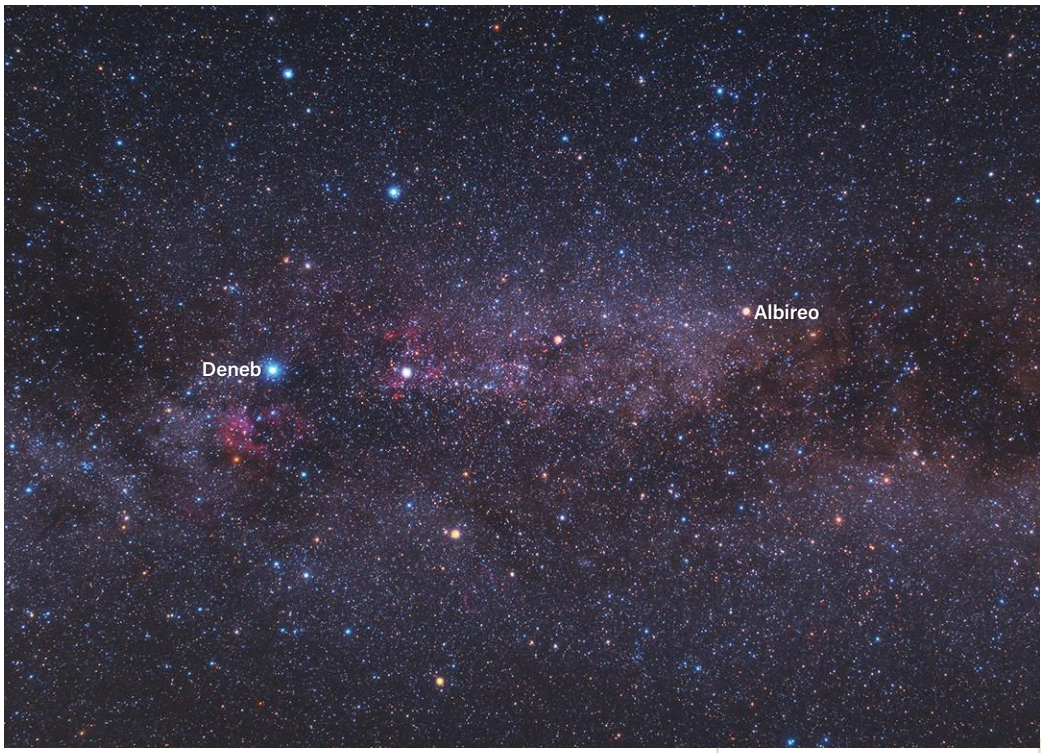
In the Dipper's handle

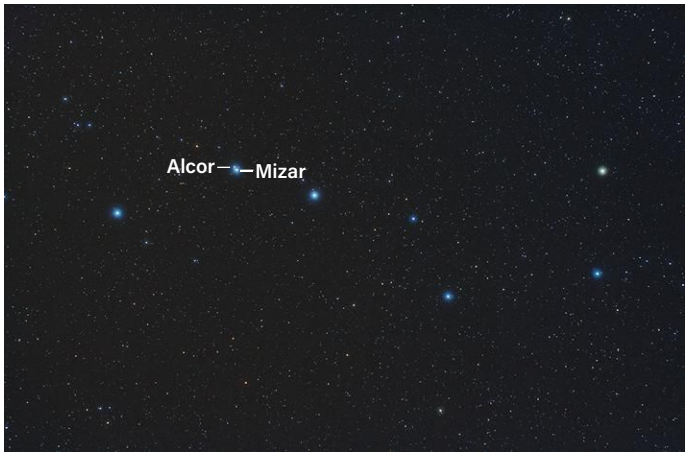
Before the summer night slips away, turn toward the northwest and find the Big Dipper. The middle star in the Dipper's handle — Mizar (Zeta [ζ] Ursae Majoris) — has long been a favorite showpiece at star parties.

Telescope operators ask people to look at Mizar with just their eyes: "How many stars can you see?" A few visitors will say they can see a second faint star near Mizar; binoculars will easily separate these two stars. At low power in a telescope, Mizar appears white while its companion, Alcor (80 UMa), looks vivid blue. Or does it? The 19th-century astronomer Reverend T.W. Webb recorded seeing the pair as white and green.

However, there are no green stars. So why might Alcor appear that way? The pupil is only fully open when the eye is fully dark-adapted. Under this condition, the cones that give us our color vision have stopped working and the rods have taken over, reducing our ability to see subtle shades.

Artists have long known that contrasting colors can increase the boldness of a painting, and this effect works with stars, too. Rods are most sensitive to blue light. When looking at a bright white star such as Mizar, the contrast can enhance the blue color of a star like Alcor. Experiments have shown that at times our perception of green will dominate over blue. This may explain why many observers have recorded shades of green in double stars.





ABOVE: Deneb, the brightest star in Cygnus the Swan, is part of the Summer Triangle. But the star every telescope operator at a summer star party targets is Albireo. TONY HALLAS

LEFT: The wide double star Mizar and Alcor in Ursa Major appears white and blue, respectively. TOM DIANA

The summer showpiece

Before the night is over, find Vega again. To the southwest, you'll see Altair, the brightest star in Aquila the Eagle. Completing the Summer Triangle is Deneb in the tail of Cygnus the Swan. The head of the Swan, Albireo (Beta Cygni), lies roughly in the center of the Triangle. This is the double star that many observers target at summer star parties.

Albireo is a great example of how contrast can enhance star colors. To the unaided eye, it appears a dull white. But through a telescope, Albireo resolves into a double star that most observers see as gold and sapphire. The color variation is due to the difference in the surface temperatures of these two stars. The yellow primary is a relatively cool 7,500 F (4,150 C). The secondary, on the other hand, has an incredible surface temperature of 23,000 F (12,760 C) and radiates visible light mostly in the blue part of the spectrum.

Stargaze a while

Throughout the year, the parade of colorful stars continues. In the fall, look toward Cepheus the King and Auriga the Charioteer, and in winter, the constellation Orion the Hunter hosts copper-hued Betelgeuse and brilliant blue Rigel. It's tempting for us to test our eyes and telescopes to view nebulae and distant galaxies. But don't forget to take time for the subtle and colorful points of light that glow softly in the night sky.

Raymond Shubinski *is a contributing editor of* Astronomy *who observes hot stars from cold St. Joseph, Michigan.*

SKY THIS MONTH

Visible to the naked eye
Visible with binoculars
Visible with a telescope

THE SOLAR SYSTEM'S CHANGING LANDSCAPE AS IT APPEARS IN EARTH'S SKY.

BY MARTIN RATCLIFFE AND ALISTER LING

Venus (upper left) shines amid the Hyades star cluster in Taurus, with Aldebaran to its lower right. This scene, captured in 2017, will repeat midmonth. ALAN DYER

Venus tracks through Taurus

Summer nights offer lots of interesting sights this month. Mercury and Mars are on show in the evening twilight. Both Uranus and Neptune stand near brighter beacons: Neptune and Saturn are two Moon-widths apart all month, while the morning sky hosts Venus and Uranus together in Taurus. Saturn also shows off two Titan shadow transits, visible through small telescopes. Jupiter returns late in the month, as Pluto reaches opposition.

Mercury hangs low in the west soon after sunset, shining brightly at magnitude 0.4. It outshines Regulus, Leo's brightest star, by a full magnitude.

Mercury stands 1° southwest of the Beehive Cluster (M44) on the 2nd. If you have a clear western horizon and transparent air, binoculars may show a fuzzy hint of M44 in the darkening twilight, although any horizon haze will wash it out.

Mercury reaches its greatest eastern elongation on the 4th, 26° east of the Sun. The planet now stands 4° high an hour after sunset. The 4th-magnitude star Asellus Australis (Delta [δ] Cancri) lies 20" from Mercury, although the star will be hard to see through any haziness.

If your scope can resolve Mercury's 8"-wide disk at low altitude, it is 45 percent lit on the 1st. It slims to 39 percent by the 4th and to 22 percent by the 14th, when it spans 10".

Mercury's visibility diminishes quickly in the second week of July, dimming to magnitude 1 by the 12th and magnitude 1.5 by the 17th. Additionally, Mercury stands only 2° high 40 minutes after sunset on the 15th. You can try catching it earlier, but the sky is brighter and Mercury's faint glow will be increasingly challenging each consecutive evening.

Mercury drops from view quickly and reaches inferior conjunction with the Sun at the end of the month.

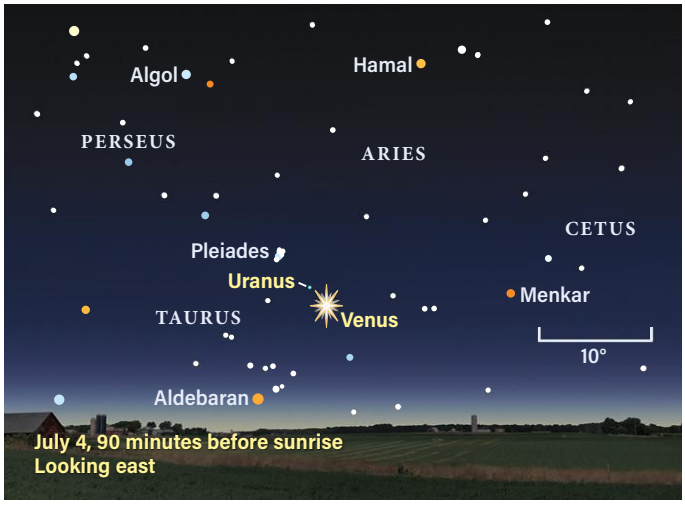
Mars starts the month at magnitude 1.4, visible low in the west after sunset. It drops by 0.2 magnitude for the latter half of July. Throughout the month, Mars travels across southern Leo. On July 1, the Red Planet stands 8° west of Regulus and is 22° high one hour after sunset.

Also on the 1st, a fine waxing Moon lies 24° southeast of Mars. On July 27, a slimmer crescent Moon stands 8.5° west of Mars — the same day Mars crosses from Leo into Virgo. The Moon stands 4° southeast of Mars on the following night, July 28. Look an hour after sunset, because now Mars is only 12° high in the western sky.

Even through a telescope, Mars' disk shows little detail, due to its small angular size (less than 5" by the end of the month). While the Red Planet remains visible for many months in the evening sky, the telescopic view doesn't improve.

This summer is a great time

Lined up



Early on the morning of July 4, use Venus and the Pleiades to guide your view to distant Uranus, visible with binoculars. ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

OBSERVING HIGHLIGHT

VENUS passes 2° south of **URANUS** late on July 3. They still lie relatively in line early on July 4.

to spot **Neptune**. All you need is binoculars. Neptune remains about 1° north of **Saturn** all month, making it easier to identify than usual. A waning gibbous Moon stands 3° north of Saturn on July 16, with Neptune nestled between them.

Saturn and Neptune rise together around midnight local daylight time. Saturn shines at magnitude 0.9 and is an easy object low in the eastern sky an hour after it rises. Neptune is magnitude 7.7 and is obvious north of Saturn in a low-power telescope eyepiece. Viewing both planets together is rare. Consider the amazing fact that Neptune lies nearly 1.9 billion miles beyond Saturn!

The two planets lie in Pisces, southeast of the Circlet. They're well placed in the two hours before dawn, more than 40° high in the southeastern sky. Both Saturn and Neptune reach a stationary point in their easterly motion. Neptune halts on the 5th, and Saturn on the 14th. Watch each night as their relative positions slightly change, the two distant planets performing an elegant slow dance.

Neptune spans a mere 2" and reveals a bluish hue through a telescope. Saturn's disk spans 18", an easy target in any telescope. We have a fine view of the southern face of the rings, which are tilted some 3.6° to our line

— *Continued on page 34*

RISING MOON | The end of the standstill

Swing low

The July Full Moon arcs low through the southern sky in this composite, which shows the Moon's position every 10 minutes on July 9/10, 2017. ALAN DYER

THERE'S A SHIFTING PATTERN of moonrises at Full phase that caught the eyes of the ancients. It's just finished bottoming out, making an easy start for you to ride the wave of the next 18.6-year cycle. Echoing the way winter sunrises head to the southeast, stop at the solstice, and return northward, Luna's summer moonrises do the same but with a surprise. This year, the moonrises are an extra 7° farther south, quite a lot for an avid watcher of the skies. Halfway into the cycle — in 2034 — they will fall 7° closer to the east.

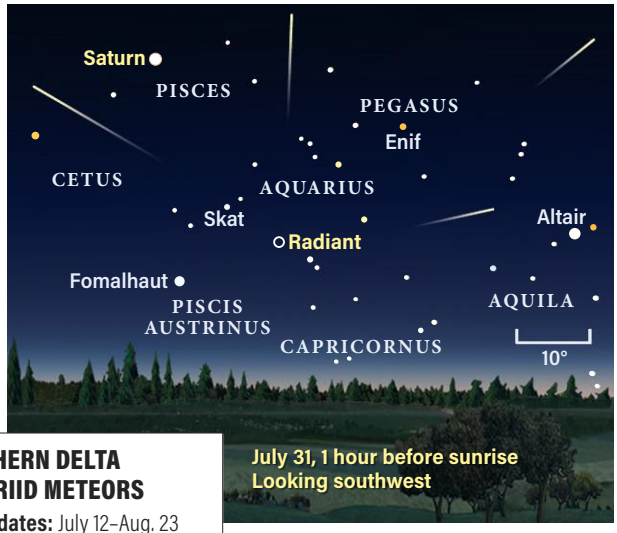
It's easier to notice this lunar standstill when you have prominent features at the horizon, like hills or notches, or distant trees or buildings. Most importantly, you'll need a viewing location to which you can reliably return. You'll have four chances from the 7th through the 10th to spot the Moon rise at its farthest south.

To help visualize this, look how the blue line of the Moon flows on the Paths of the Planets diagram, low through Scorpius and Sagittarius, high in Taurus and Gemini. This is the 5° tilt of the lunar orbit, rotating like a twirling hula hoop's contact point. The high point will be in Pisces in a few years.

Watch for the Full Moon's shallower rise angle and extra-low arc across the southern sky. With more atmosphere to pass through, Luna's face will be yellower, even pale orange.

METEOR WATCH | Double feature

Southern Delta Aquariid meteor shower



The Southern Delta Aquariids peak on the last day of the month. Although Neptune lies near Saturn, it is not shown here because it is not visible to the naked eye.

SOUTHERN DELTA AQUARIID METEORS

Active dates: July 12–Aug. 23
Peak: July 31
Moon at peak: Waxing crescent
Maximum rate at peak: 25 meteors/hour

THE SUMMER meteor season begins in July. The combination of a few minor showers with low hourly rates contributes to a strong chance of catching a meteor during the dark moonless hours of night.

The Southern Delta Aquariids are active starting the 12th and build slowly through the first three weeks of July. Near the peak on July 31, if the radiant were overhead it would produce about 25 meteors per hour. The radiant is near the 3rd-magnitude star Skat in Aquarius, and climbs to 25° altitude from North America in the hour before dawn. Watch for maybe a dozen meteors per hour.

This shower is joined by the start of the annual Perseids July 17, so by the end of July you can expect a few meteors per hour from a very different direction than Aquarius. It's fun to see if you can identify members of both showers on a clear morning.

STAR DOME

HOW TO USE THIS MAP

This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

midnight July 1
11 P.M. July 15
10 P.M. July 31

Planets are shown at midmonth

MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

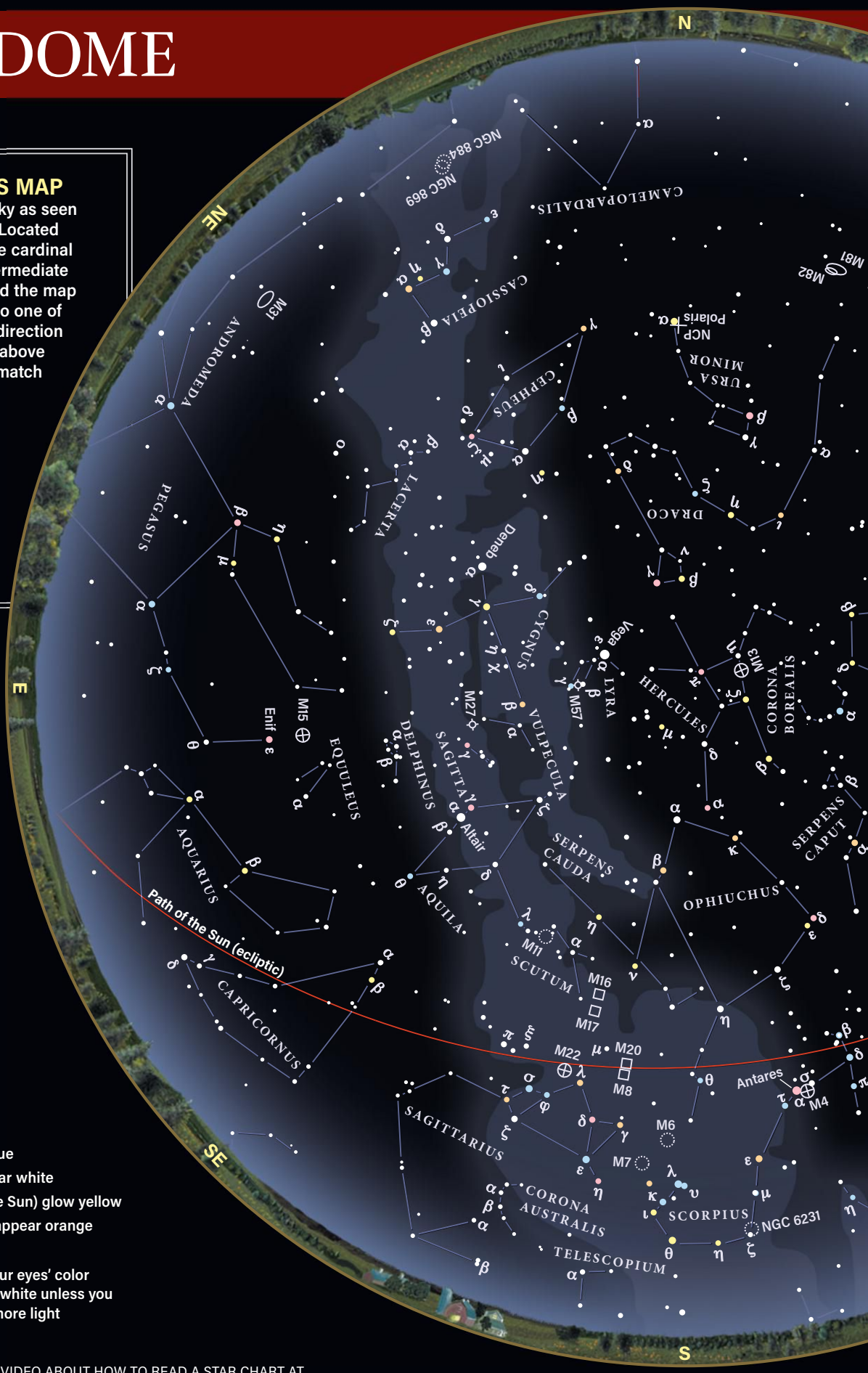
STAR MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light



BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**

JULY 2025

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

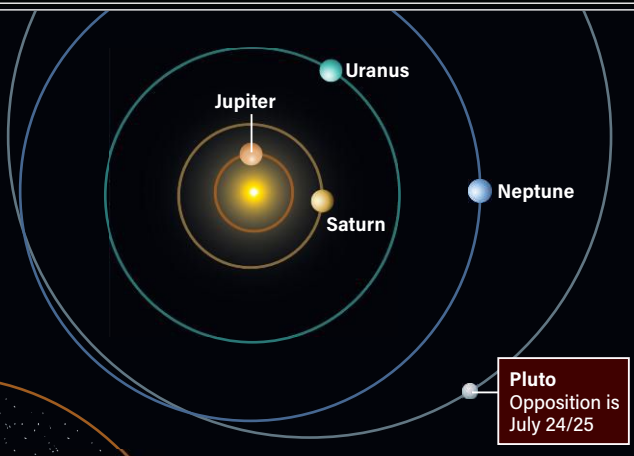
2 First Quarter Moon occurs at 3:30 P.M. EDT
3 Earth is at aphelion (94.5 million miles from the Sun), 4 P.M. EDT
The Moon passes 0.8° south of Spica, 6 P.M. EDT
Venus passes 2° south of Uranus, 9 P.M. EDT
4 Mercury is at greatest eastern elongation (26°), 1 A.M. EDT
The Moon is at apogee (251,423 miles from Earth), 10:29 P.M. EDT
5 Neptune is stationary, 11 A.M. EDT
7 The Moon passes 0.4° south of Antares, 2 P.M. EDT
10 Full Moon occurs at 4:37 P.M. EDT
11 The Moon passes 0.02° north of Pluto, 7 P.M. EDT
13 Venus passes 3° north of Aldebaran, midnight EDT
14 Saturn is stationary, 4 A.M. EDT
Asteroid Juno is stationary, 6 A.M. EDT
16 The Moon passes 3° north of Neptune, 6 A.M. EDT
The Moon passes 4° north of Saturn, 7 A.M. EDT
17 Mercury is stationary, 3 A.M. EDT
Last Quarter Moon occurs at 8:38 P.M. EDT
20 The Moon passes 5° north of Uranus, 9 A.M. EDT
The Moon is at perigee (228,690 miles from Earth), 9:55 A.M. EDT
21 The Moon passes 7° north of Venus, 3 P.M. EDT
22 The Moon passes 5° north of Jupiter, midnight EDT
24 New Moon occurs at 3:11 P.M. EDT
25 Pluto is at opposition, 3 A.M. EDT
26 The Moon passes 1.3° north of Regulus, 4 P.M. EDT
28 The Moon passes 1.3° south of Mars, 4 P.M. EDT
31 The Moon passes 1.0° south of Spica, 2 A.M. EDT
Southern Delta Aquariid meteor shower peaks
Mercury is in inferior conjunction, 8 P.M. EDT

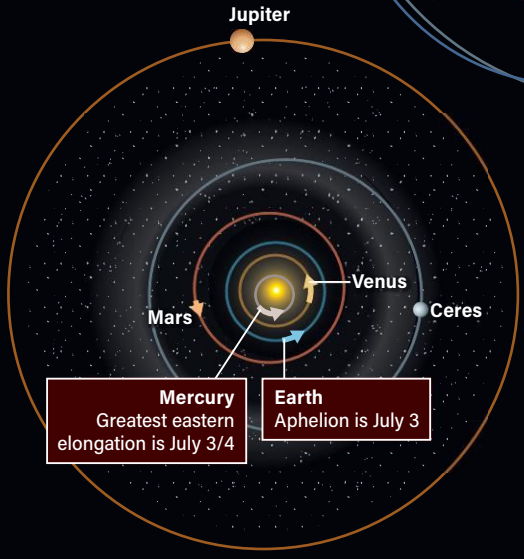
PATHS OF THE PLANETS

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

THE PLANETS IN THEIR ORBITS

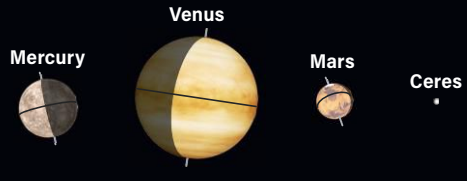
Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at midmonth from high above their orbits.





THE PLANETS IN THE SKY

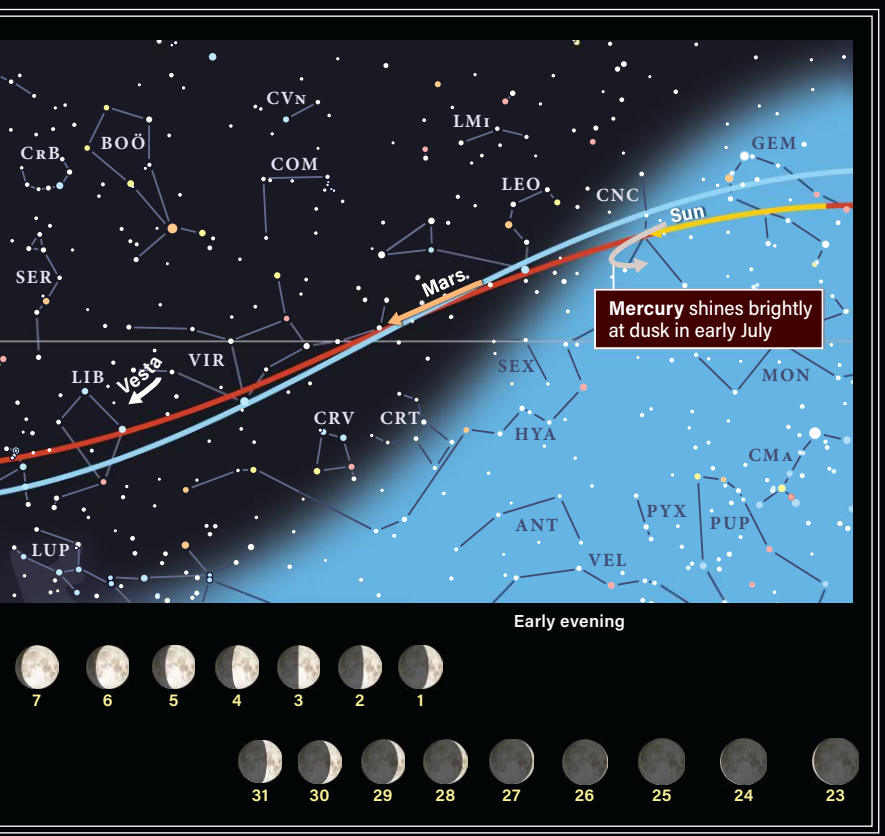
These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets at 0h UT for the dates in the data table at bottom. South is at the top to match the view through a telescope.



PLANETS	MERCURY	VENUS
Date	July 1	July 15
Magnitude	0.4	–4.1
Angular size	7.6"	16.0"
Illumination	46%	69%
Distance (AU) from Earth	0.884	1.042
Distance (AU) from Sun	0.442	0.726
Right ascension (2000.0)	8h29.0m	4h39.8m
Declination (2000.0)	19°38'	19°53'

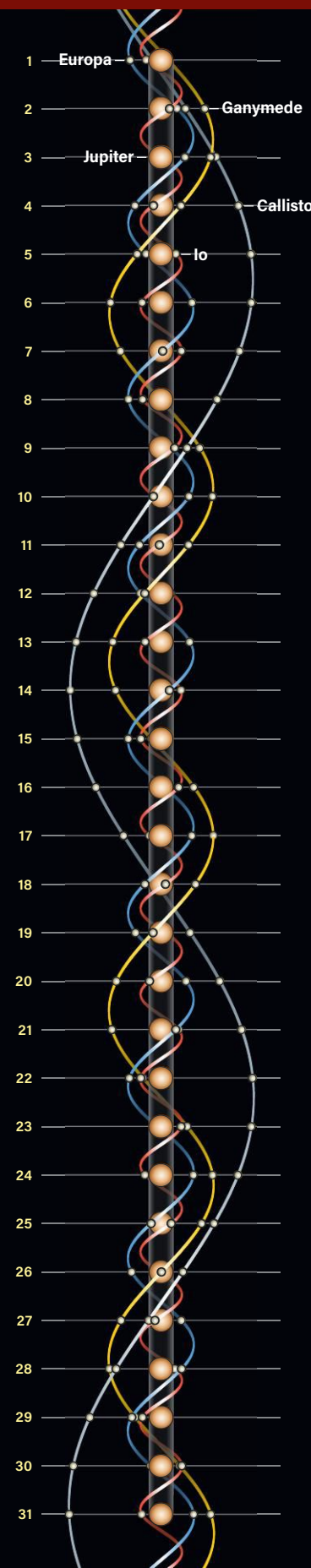
This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

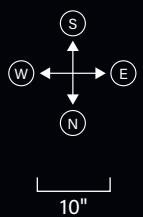
JULY 2025

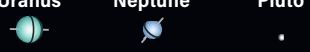


JUPITER'S MOONS

Dots display positions of Galilean satellites at 6 A.M. EDT on the date shown. South is at the top to match the view through a telescope.



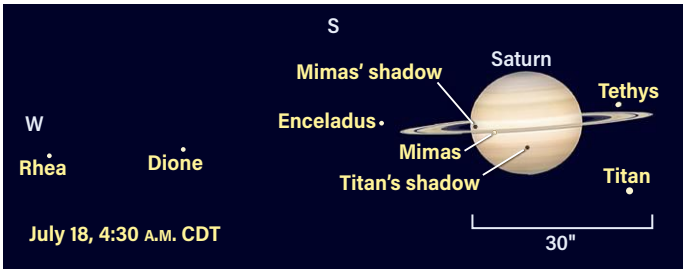




MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
July 15	July 15	July 31	July 15	July 15	July 15	July 15
1.5	8.9	–1.9	0.9	5.8	7.7	15.1
4.6"	0.5"	32.6"	18.1"	3.5"	2.3"	0.1"
93%	97%	100%	100%	100%	100%	100%
2.018	2.653	6.044	9.162	20.123	29.516	34.305
1.628	2.969	5.156	9.571	19.520	29.889	35.304
11h08.4m	1h10.9m	6h48.4m	0h09.4m	3h51.4m	0h08.7m	20h22.6m
6°25'	–5°18'	22°53'	–1°29'	19°56'	–0°31'	–23°15'

 — Continued from page 29

Spot the shadow



Saturn's moon Titan throws its shadow onto the planet's disk twice this month. Note that while 13th-magnitude Mimas and its shadow are also transiting at the same time on July 18, they will likely be invisible.

of sight. Watch for any unusual bright cloud features on Saturn's disk.

Titan, Saturn's largest moon, shines at magnitude 8.5. It's easy to spot in small telescopes as it circles the ringed planet every 16 days. Due to the shallow tilt of its orbit, Titan's shadow transits Saturn's disk, and the next couple of months offer repeat opportunities to view this.

Titan's shadow begins a transit July 2 around 3:30 A.M. EDT. It takes a few minutes for the shadow to appear and will depend somewhat on your seeing conditions. By 4 A.M. EDT, the shadow should be distinctly visible on Saturn's disk, and West Coast observers will have a chance to see the later stages as Saturn rises. The full shadow transit takes more than five hours; the shadow is roughly midway across the disk by dawn across the Midwest. Titan itself passes north of the disk.

There's a repeat shadow transit July 18 starting about 2:50 A.M. EDT. It reaches midway across Saturn's disk around 4:30 A.M. CDT, just as dawn breaks across the East Coast, with the latter half of the transit visible from the western half of the U.S.

Saturn has a host of other moons. The most visible are Tethys, Dione, and Rhea, all within Titan's orbit and shining at 10th magnitude. Enceladus orbits just outside the edge of the rings and shines at 12th magnitude, challenging to spot with the brilliant disk of Saturn dominating a telescopic view.

Iapetus lies 1.4' due south of Saturn on July 1, shining near 11th magnitude. It then heads east of the planet, dimming to 12th magnitude by the time it reaches greatest eastern elongation on the 21st, when it stands 9' from Saturn. The dimming is due to the darker half of Iapetus rotating to face Earth.

Venus and **Uranus** are located in the same region of Taurus the Bull in early July. Venus is obvious, shining at magnitude –4.1 and rising around 3 A.M. local daylight time. Uranus is nicely placed 4° due south of the Pleiades (M45).

Uranus shines at magnitude 5.8, making it an easily binocular object. Venus lies in the same vicinity for a few days in early July, aiding its identification. On July 4, Uranus is 2.4° due north of Venus. There's also a nice pair of 6th-magnitude stars due west of Uranus. A telescope will show the ice giant's pale bluish-green, 3.5"-wide disk.

Venus moves east as July progresses and stands 3° due north of Aldebaran on the 14th, after skirting the northern regions of the Hyades cluster for a few days. A crescent Moon stands nearly 8° northwest of Venus on the morning of the 21st. On the morning of the 26th, Venus lies 44' northwest of Zeta (ζ) Tauri, the southern "horn" of Taurus.

Deep-sky observers will recognize this location as very

WHEN TO VIEW THE PLANETS

EVENING SKY
Mercury (west)
Mars (west)

MIDNIGHT
Saturn (east)
Neptune (east)

MORNING SKY
Venus (east)
Jupiter (east)
Saturn (south)
Uranus (east)
Neptune (south)

COMET SEARCH | Magnitude mashing

WHEN COMET C/2023 A3 (Tsuchinshan-ATLAS) reached magnitude –6 last October, why was Venus, two magnitudes *fainter*, easier to see? A more compact light source punches through skyglow, while diffuse light from an expansive comet tail is too faint to compete with the twilight.

A comet's integrated magnitude comes from adding together the light from its tail as if it were compressed into a star. Comet discoverer David Levy recommends the in-out method to visually estimate a comet's total brightness at the telescope. In a nutshell, study the comet's in-focus apparent size and average brightness through the eyepiece. Now find a slightly brighter star, take it out of focus to make it the size of the comet, and compare. Jump to different stars until you get a reasonable match. Notice how much the star fades the bigger you make it, perhaps to disappearance.

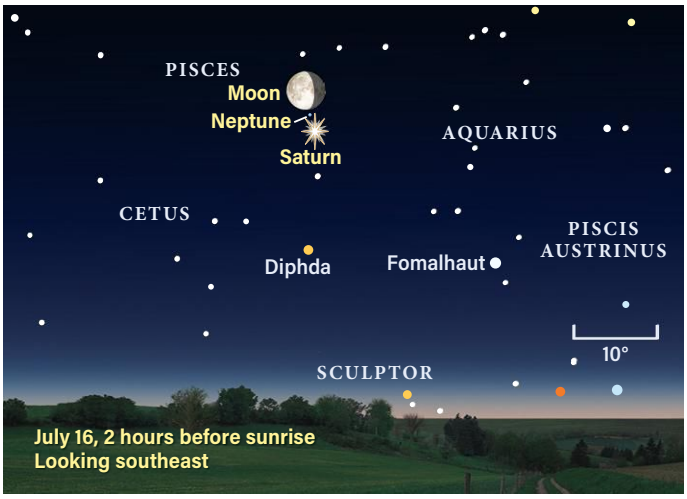
Starry testbed

The 7th-magnitude globlar cluster M28 serves as a starting point to practice the in-out method of visually estimating a comet's magnitude. GARY IMM

Practice on some globulars, clustered near our galactic center. Start with M28 at the top of Sagittarius' Teapot. Compare the in-focus magnitude 6.8 M28 with the out-of-focus three stars to the west and southwest. Don't expect precision at this stage. Try it with fainter magnitude 9.0 NGC 6638 and magnitude 9.1 NGC 6642. Then there's the real challenge: magnitude 11.0 Palomar 8 a few degrees north. Use M22 as a substitute binocular comet. The in-out method gets easier the more you practice.

Comet C/2024 E1 (Wierzchoś) breaks past 13th magnitude next month, perhaps reaching magnitude 5.5 in January.

Distant world



On July 16, Neptune (visible with binoculars or a small scope) lies between Saturn and the gibbous Moon.

close to M1, the Crab Nebula. The nebula stands 0.5° north of Venus. It'll be interesting to try to see M1 and Venus in the same field of view — watch for any spurious lens flare from Venus masquerading as the nebula. Small nudges to your scope will reveal which smudge is M1.

A telescope will show Venus' changing appearance. On July 1, it spans 18" and reveals a 64-percent-lit gibbous phase. By the 31st, it has grown to 75 percent lit and 14" across. Venus spends the last three days of July in northwestern Orion.

Jupiter reappears in the morning sky in late July. The gas giant lies in western Gemini, shining at magnitude –1.9 and rising shortly before 5 A.M. local daylight time on the 14th. Watch the eastern horizon on July 23 as Jupiter rises soon after 4 A.M. local daylight time, along with a fine crescent Moon 5.5° to its left (northeast). By the end of July, Jupiter is clear of the horizon, along with all the stars of Gemini, just as dawn breaks.

Pluto reaches opposition July 25. The dwarf planet is 3.2 billion miles from Earth, wandering among the stars of southwestern Capricornus at a declination of –23°, well south of the ecliptic. Consequently, it never rises very high. This month is the best opportunity to see it, as it lies due south at its highest elevation at 1 A.M. local daylight time.

The dwarf planet glows at magnitude 15.1; detecting it visually will require a large telescope exceeding 16 inches and dark observing conditions. There's some help near Pluto's location: two stars at magnitude 7.7 and 7.8 that sit side by side, aligned east-west. The stars stand 39' apart. Find them by starting at 4th-magnitude Psi (ψ) Capricornus. Move 5.2° northwest to find the easternmost star in the pair. Pluto is 22' due north of this star on June 25 and wanders westward throughout July. It forms an equilateral triangle with the two stars on July 12, and skirts 1' to 2' south of a 10th-magnitude star over the next two nights. A note of caution here: The 10th-magnitude star has a 15th-magnitude star just 43" due south of it. On July 13, Pluto lies at double that separation and is slightly fainter.

On the 26th, one day after opposition, Pluto reaches a point 9' due north of the westernmost 8th-magnitude star previously mentioned. Note there are many 12th- and 13th-magnitude stars in the same region of Capricornus.

If you already have a nice astrophotography setup with your telescope, recording Pluto requires only a couple of minutes of exposure with a cooled camera. Targeting the two 8th-magnitude stars with a system that has at least a 30'-wide field of view will also capture Pluto.

Martin Ratcliffe *is a planetarium professional with Evans & Sutherland and enjoys observing from Salt Lake City.* **Alister Ling**, *who lives in Edmonton, Alberta, is a longtime watcher of the skies.*

GET DAILY UPDATES ON YOUR NIGHT SKY AT **www.Astronomy.com/skythisweek.**

LOCATING ASTEROIDS
Snap sightings

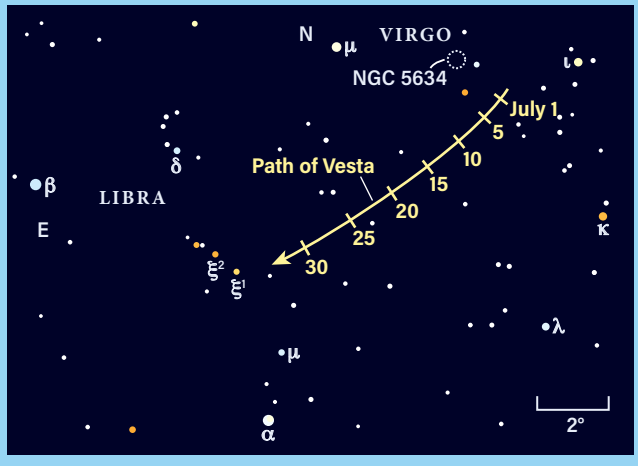
WHEN YOU CAN'T TAKE THE TIME for a full session, even 10 minutes of observing helps you relax after a long day and before the next one. Step outside with binoculars and you'll be seeing asteroid 4 Vesta within a few breaths.

Familiarize yourself with Alpha (α) and Beta (β) Librae almost due south as twilight fades, halfway between luminaries Spica and Antares. It will take six weeks for Vesta to split these stars, time for you to have a quick peek every three or four nights and notice it shift toward Antares. As July opens, Vesta lies between the feet of Virgo, Mu (μ) and Kappa (κ) Virginis, a fainter echo of Libra's lights.

If you're using a scope to follow the main-belt world, give the distant globular cluster NGC 5634 a try. From the suburbs, its core should mimic a fuzzy 10th- to 11th-magnitude star. Avoid the first week of the month, when the bright Moon is not far.

There are so few background stars here that a go-to scope from the city will land you on Vesta with nothing else in a 1° field of view. The slow fade from magnitude 6.7 to 7.2 comes as Earth leaves it behind. On the 19th, the 330-mile-wide space rock pretends to be the brighter component of a wide, unequal double star. July 19–21 and 30–31 are good chances to see Vesta move compared to other stars at low power over a run of nights.

Bright lights



Bright Vesta will be easy to spot this month, curving away from Virgo toward Alpha and Beta Librae.

EXPOSING THE INTERSTELLAR MEDIUM

The penetrating eye of JWST brings Cassiopeia A's surroundings into focus. BY RICHARD TALCOTT

ROUGHLY 11,000 YEARS AGO, a massive star in the constellation Cassiopeia reached the end of its all-too-brief life. When the star's iron core collapsed, it triggered a shock wave that ripped the rest of the star apart and lit up its small corner of the galaxy.

Unfortunately for earthbound observers, thick dust clouds in the Milky Way absorbed most of the supernova's light, and what little got through failed to make an impression when it reached our planet some 350 years ago. The first definitive sighting came in the 1940s, when radio astronomers detected its remnant as the brightest radio source in Cassiopeia. That distinction earned it the name Cassiopeia A (Cas A for short). Optical astronomers didn't spot the remnant until a few years later in 1950.

A PERFECT LABORATORY

At a distance of only 11,000 light-years, Cas A makes an ideal target for studying a supernova and its aftermath. The James Webb Space Telescope (JWST) has viewed Cas A several times in the past three years. Early on, it concentrated on the 10-light-year-wide shell of material the explosion ejected. (See "A tangled web of debris" in the October 2023 issue.)

Now, astronomers have shifted their focus to the interstellar medium well beyond the remnant's sphere of influence. Jacob Jencson of IPAC at Caltech in Pasadena, California, led a team that used JWST to explore the dusty environment surrounding Cas A. The researchers reported their findings at the January meeting of the American Astronomical Society in National Harbor, Maryland.

When the explosion's original shock wave breached the star's surface, it generated an intense burst of X-rays and ultraviolet radiation that continues to spread out at the speed of light. As that pulse of energy encounters interstellar gas and dust, it warms the material enough for it to glow at infrared wavelengths — right in JWST's wheelhouse. In essence, we see the supernova's initial burst reverberating across the interstellar medium as a thermal light echo.

Jencson's team targeted a light echo some 230 light-years from the Cas A remnant. The scientists viewed the echo three times from Aug. 19 to Sept. 30, 2024, watching for changes that will help illuminate the interstellar medium's 3D structure.

"We were pretty shocked to see this level of detail," said Jencson. JWST resolves the structures into fine filaments that appear to be sculpted by magnetic fields. The telescope reveals features as small as 400 astronomical units across, or just five times the diameter of Pluto's orbit around the Sun. (One astronomical unit, or AU, is the average Earth-Sun distance of 93 million miles [150 million kilometers].)

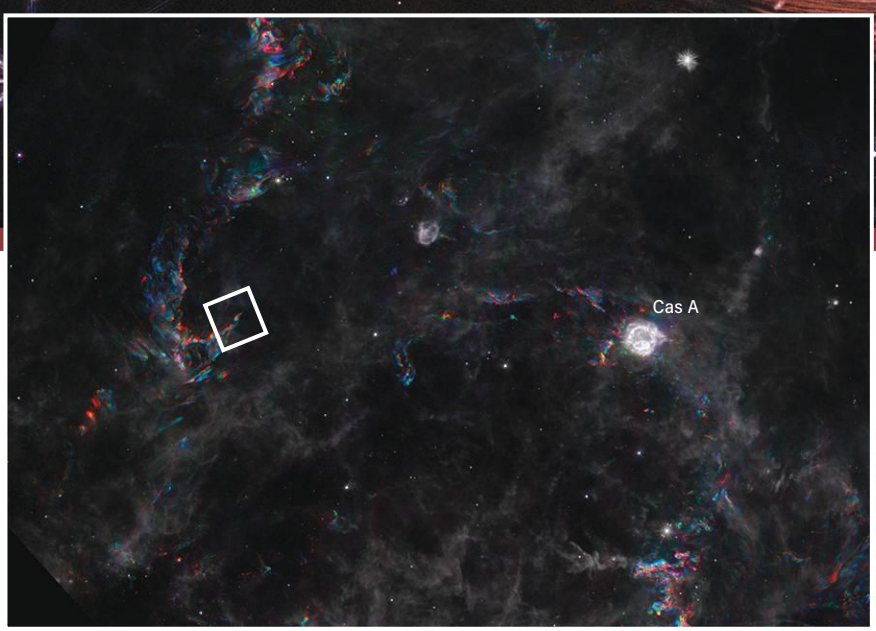
"We did not know that the interstellar medium had structures on that small of a scale," added team member Josh Peek of the Space Telescope Science Institute in Baltimore. "We think every dense, dusty region that we see, and most of the ones we don't see, look like this on the inside."

WHAT LIES AHEAD

The astronomers will continue imaging Cas A's light echoes, and also plan to take spectra of the glowing material. Spectroscopy should open a new window into the structure of the interstellar medium surrounding Cas A.

"We can observe the same patch of dust before, during, and after it's illuminated by the echo and try to look for any changes in the compositions or states of the molecules, including whether some molecules or even the smallest dust grains are destroyed," said Jencson.

Contributing Editor **Richard Talcott** *wrote about JWST's observations of planet-forming disks in the Small Magellanic Cloud in the June issue.*



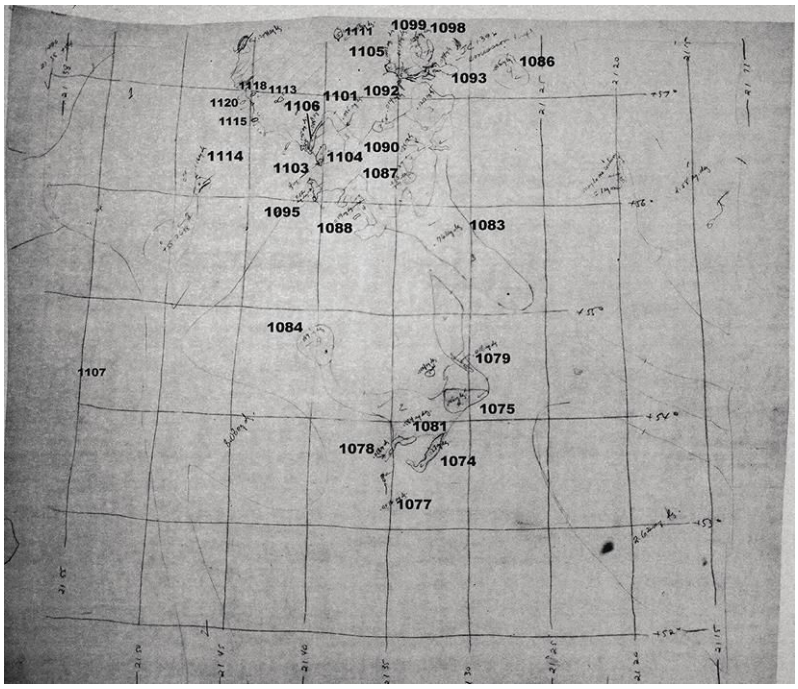
ABOVE: Tightly packed ribbons glow in infrared light as gas and dust radiate from the effects of the supernova blast that created Cassiopeia A. JWST captured this thermal light echo Aug. 19, 2024, the first of three observations to look for changes in the interstellar medium. NASA, ESA, CSA, STSCI, JACOB JENCSON (CALTECH/IPAC)

LEFT: NASA's Spitzer Space Telescope took a series of six infrared images of Cassiopeia A and its surroundings from 2005 to 2008. In this composite, dust features in blue and orange represent changes as light echoes spread outward; gray areas showed no changes. The square highlights the area JWST imaged at high resolution. NASA/JPL-CALTECH/Y. KIM (UNIV. OF ARIZONA/UNIV. OF CHICAGO)

BEVERLY LYNDS and her dark nebulae

Correctly identifying Lynds' dark nebulae has become a labor of love for one amateur astronomer.

TEXT AND IMAGES BY RODNEY POMMIER



IF YOU ARE A FREQUENT READER OF *Astronomy*, then you likely have seen images on its pages of objects from the famous Lynds' *Catalogue of Dark Nebulae*. These mysterious dark clouds of interstellar dust are denoted by the letters LDN followed by a catalog number, such as LDN 881.

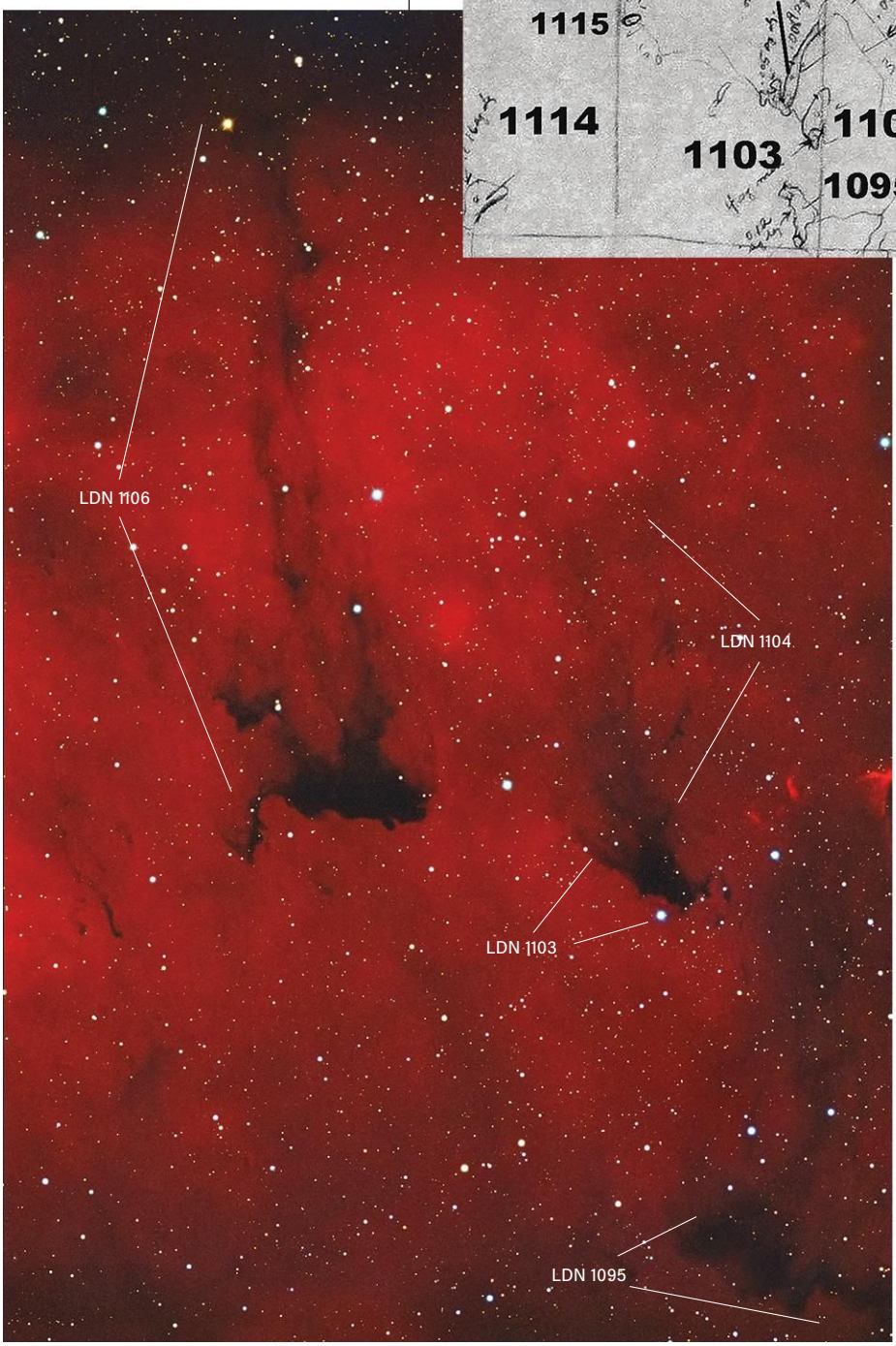
I have contributed some of those images. I and many other astroimagers have also contributed images of bright nebulae that happen to contain LDN objects. While the LDNs aren't always mentioned in the captions, their presence provides stark contrast that certainly makes those images more dramatic and captivating. For example, the North America Nebula (NGC 7000) wouldn't resemble that continent so strongly if it didn't have LDN 935 posing as the Gulf of Mexico.

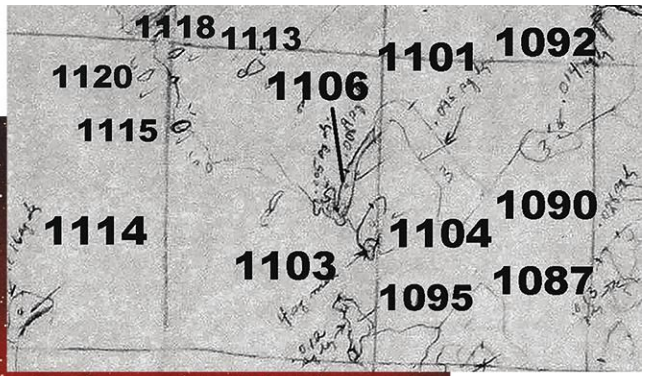
To permit proper identification of LDNs in astroimages, the author examines microfilm images of Lynds' original tracings of dark nebulae (like this one within IC 1396) made by laying tracing paper over the plates of Palomar Observatory Sky Survey Number 1. He then labels each outline with its corresponding LDN number from her catalog.

Beverly Turner Lynds poses with the author's telescope in his backyard observatory in May 2024.

BELOW: The author imaged several LDNs in IC 1396 north of the Elephant Trunk Nebula. Methods to identify the LDNs within this image using currently available resources resulted in misidentification of several nebulae and no identification of others.

RIGHT: This zoomed-in view of Lynds' tracing sheet is for the region of sky covering IC 1396. Comparing the shapes of the nebulae in the author's image with the outlines on Lynds' tracing paper clearly shows that the long, streaming dark nebula beginning at top left of the image and ending in a dark irregular globule near the center is LDN 1106. The triangular dark nebula to its lower right is LDN 1103, the streaming portion above it is LDN 1104, and the irregularly shaped dark nebula in the lower right corner is LDN 1095.





The Lynds' Catalogue of Dark Nebulae was compiled by American astronomer Beverly Turner Lynds, who died peacefully at a hospice in Portland, Oct. 5, 2024, after suffering a stroke in early September. She was 95 years old. I am honored to say that Beverly was one of my nearest and dearest friends.

While researching her, I had been pleasantly surprised to discover she lived only a few miles from me. I contacted her and was delighted to hear she knew about me from reading my articles in *Astronomy*. She knew from my article bylines that I also live in Portland and wondered if we might meet.

After our first meeting, we immediately became best astronomy buddies. We regularly met for lunches at our favorite restaurants or our homes. We exchanged email messages almost daily and she loved visiting my backyard observatory. She would entertain me for hours with stories about all the famous astronomers she knew and with whom she had worked.

More importantly, I learned a great deal about her remarkable life and am delighted to tell her story, and the story behind her dark nebulae catalog, here.

A storied career

Beverly Turner was born in Shreveport, Louisiana, on Aug. 19, 1929. Her family moved to New Orleans when she was three, but she later returned to Shreveport to attend Centenary College of Louisiana, where she decided to become a professional astronomer. She applied to four graduate astronomy programs and was admitted to three, but shortly after she accepted the position at the University of Chicago, the offer was withdrawn when they discovered she was a woman. (*Beverley* can be a man's name if spelled with a third *E*.) The other two programs adopted the same stance.

To strengthen her next round of applications, Lynds took additional college astronomy courses and obtained a position as assistant at Lick Observatory near San Jose, California, where she assisted Nicholas Mayall in measuring the radial velocities of galaxies and George Herbig (of Herbig-Haro objects) with spectroscopic programs using the 36-inch refractor. She was subsequently admitted to the graduate astronomy program at the University of California, Berkeley, and earned a Ph.D. in 1955 with her thesis on the spectra of white dwarfs.

During this time, she married fellow graduate astronomy student C. Roger Lynds in 1954.

In 1960, the Lyndses moved to the new National Radio Astronomy Observatory in Greenbank, West Virginia, where she assisted its director, Otto Struve (whose great-grandfather, Friedrich, compiled the Struve double star catalog), with writing an astronomy textbook. Struve also charged her with building an astronomy library from scratch, an important resource for observatories prior to the internet. She ordered a copy of the recently completed National Geographic Society–Palomar Observatory Sky Survey (1958), which was obtained with Palomar's 48-inch Schmidt telescope. The survey covers the sky north of –33° declination. When it arrived, Lynds immediately noticed how well dark nebulae showed up on its plates. She decided she could compile a catalog of dark nebulae that would be superior to that published by Edward Emerson Barnard in 1927.

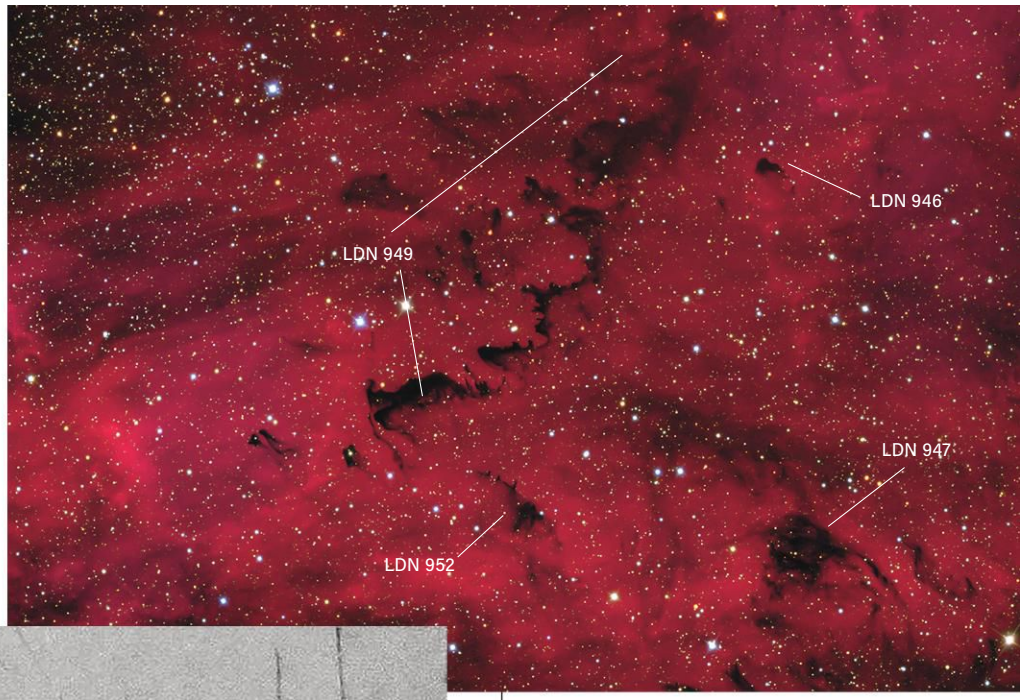
Lynds spent hours tracing the outline of each dark nebula visible on the plates onto sheets of tracing paper. She recorded their epoch B1950.0 coordinates, measured their area in square degrees with a calibrated planimeter, and estimated their darkness on a scale of 1 to 6.

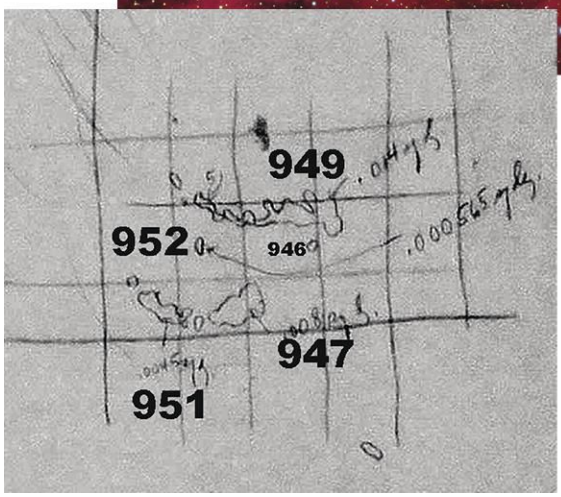
Her catalog of 1,802 dark nebulae, published in the *Astrophysical Journal* in 1962, far surpassed Barnard's and is now regarded as a landmark catalog on par with the Messier, New General, Index, and Sharpless catalogs. It currently has nearly 1,000 citations in the scientific literature. She subsequently repeated this process with emission and reflection (but not planetary) nebulae as well as supernova remnants, publishing her catalog of bright nebulae in the *Astrophysical Journal* in 1965.

She went on to study the association between dark and bright nebulae, finding their relationships easier to analyze in other galaxies than from our limited view within a spiral arm of the Milky Way. Allan Sandage lent her Edwin Hubble's glass plate images of galaxies to conduct this work. Astronomer C.C. Lin found her work supportive of his density wave theory for the formation of spiral arms in galaxies.

She subsequently studied the dust in the Trifid Nebula (M20) using the then-new technology of CCD imaging. In 1976, Lynds became Assistant Director of Kitt Peak National Observatory in Tucson, Arizona.

After retirement, she devoted much of her time to science education and reducing racial and gender disparities in the field. She served as a Shapley Lecturer for the American Astronomical Society, specifying she only wanted to visit minority colleges. She won the education award from the University Corporation for Atmospheric Research in 2013.





ABOVE: The author captured this image of a region containing several LDNs just north of the North America Nebula (NGC 7000).

LEFT: This zoomed-in view of Lynds' tracing sheet covers the region of the author's image. He was able to compare the shapes of the dark nebulae to identify them.

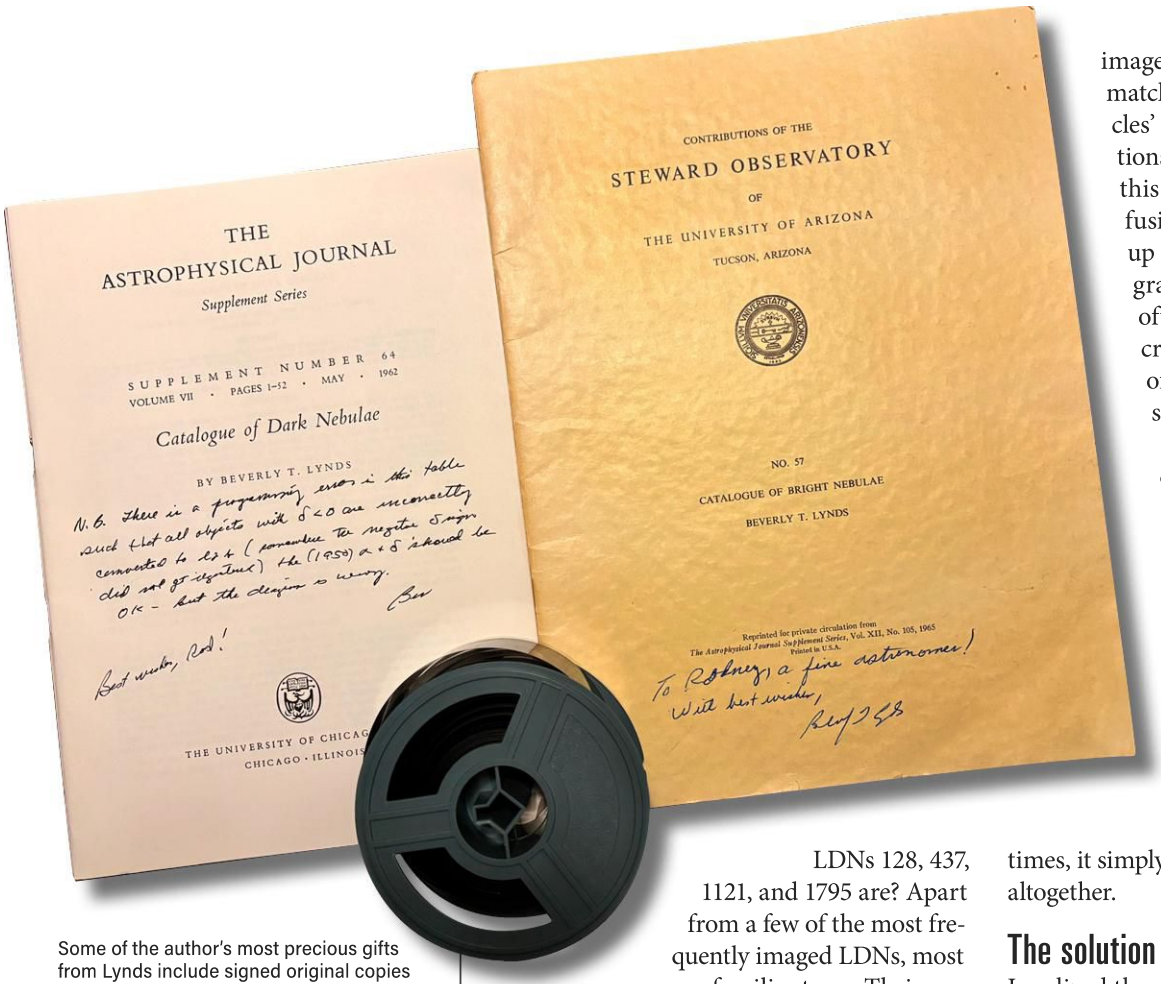
The gift of legacy

Since the beginning of our friendship, Beverly showered me with astronomy gifts, including signed books from her library, reprints of papers she published, one of Frank Drake's wine glasses with his famous Drake equation on it, and Otto Struve's personal copy of Sven Cederblad's *Catalog of Bright Diffuse Galactic Nebulae* (1946).

Two especially precious gifts are original editions of the *Astrophysical Journal* issues containing her dark nebulae and bright nebulae catalogs, which she personally autographed to me.

But her most remarkable gift to me was a reel of microfilm containing images of the sheets of tracing paper from which she made her dark nebulae catalog. As far as she knew, this is the only surviving copy of her original tracings.

I immediately recognized it as a historic astronomical treasure and knew I needed to ensure its preservation. However, I also thought I should try to do something significant with it. For preservation, I digitally scanned each microfilm frame, made multiple copies of the files, and stored them in different



Some of the author's most precious gifts from Lynds include signed original copies of her dark and bright nebulae catalogs published in the *Astrophysical Journal* in 1962 and 1965, respectively, and a reel of microfilm containing images of her tracings of dark nebulae from plates of the Palomar Observatory Sky Survey Number 1.

locations. But what could I do that would be a significant new contribution?

The problem of identification

Examining Lynds' tracings, I saw that she drew some lines of right ascension and declination on each. She wrote her measured area of each dark nebula next to its traced outline and recorded her assessment of its darkness on her scale of 1 to 6 within its outline.

She put a checkmark next to an outline to indicate she had included it in her catalog. What surprised me is that she never recorded a single catalog number next to any of the dark nebulae's traced outlines. This left me wondering as I gazed at any of her tracing sheets: "Which dark nebulae are these?"

The Lynds' Catalogue of Dark Nebulae is not photographic. It's all text and the objects are in no particular order. So who knows what the actual shapes of, say, LDNs 128, 437, 1121, and 1795 are? Apart from a few of the most frequently imaged LDNs, most are unfamiliar to us. Their recorded areas in square degrees are of no help in estimating their shape because a dark nebula with an area of, say, 0.25 square degrees could be a circular globule or a long, drawn-out filament. The area alone gives no clue.

The problem of LDN identification is more ubiquitous than you might think. I have seen many published images in which the LDN number listed in the caption is clearly incorrect. This isn't surprising, as resources to help imagers correctly identify LDNs are inadequate.

For example, when I use PixInsight software to plate solve and annotate my images containing LDNs, the program places labeled circles on the image intended to identify the LDNs, but they are always considerably offset from them. The centers of the circles don't match their 1950 coordinates in the catalog, so precession doesn't explain this problem. If the offset of a circle happens to place it just outside the field of view, then no identification is made. And the circles are sometimes not large enough to encompass the entire LDN.

When there are several LDNs on an image, I can identify them by matching the pattern of the circles' arrangement with the locations of the dark nebulae, but this can be difficult and confusing. Similarly, when I look up LDNs on the online photographic Aladin Sky Atlas, it often puts the identification crosshair over a blank region of background sky between several dark nebulae.

So, which of the many dark nebulae on the screen is the one that I want? Sometimes I can't see the size or shape of a dark nebula because the Aladin image is so underexposed that I can't discern the difference between the nebula and the background sky, even with contrast turned up to maximum. Still other times, it simply misidentifies dark nebulae altogether.

The solution

I realized the significant contribution I could make would be to identify and label each original tracing outline with its correct LDN number directly on my scanned images. Then, we would know the actual shape of each LDN based on Lynds' original tracings. This would enable correct identification of an LDN in an image by direct comparison of its shape with the shape on her original tracing.

To accomplish this, I open one of my scanned digital images of a tracing sheet in Photoshop. Next, I determine its rough coordinates based on the lines of right ascension and declination Lynds drew on the sheet. Then I browse the published catalog and begin to identify each dark nebula outline on that sheet by roughly matching the coordinates of its center with an LDN listing.

If both its area in square degrees and its darkness rating as written on the sheet for that outline by Lynds herself also match that listing in the catalog, then its identity is confirmed. Once identified, I label the traced outline on the scanned image with its correct LDN number using the Type Tool in Photoshop. After all the dark nebulae on that image have been

identified and labeled, I save the file as a new annotated version.

I have devoted many hours to this project and it will take many more to complete; some tracings of regions of the summer Milky Way have perhaps 100 dark nebulae per sheet. But once it is completed, we will have a visual resource that correctly identifies each LDN object and shows its shape just as Lynds originally defined it.

I intend to make the collection of annotated images available as a resource accessible to all astronomers and astroimagers, amateur and professional. The editors of *Astronomy* have offered to post it on Astronomy.com. I also have visited with and offered a copy to the librarian of the Royal Astronomical Society in London, who views it as an extremely valuable contribution to its considerable historical holdings.

One last puzzle

In her final years, Lynds endeavored to determine who might have been the astronomer in Walt Whitman's poem *When I Heard the Learn'd Astronomer*, which was one of her favorites. She researched this extensively to solve the mystery. She sent me frequent email updates on her progress, ultimately culminating in her final opinion: astronomer Ormsby Macknight Mitchel, the first American popularizer of astronomy. Here's the poem:

RIGHT: Lynds poses with the author and his telescope in his backyard observatory in May 2024.

When I Heard the Learn'd Astronomer by Walt Whitman

When I heard the learn'd astronomer,
When the proofs, the figures, were ranged in columns before me,
When I was shown the charts and diagrams, to add, divide, and measure them,
When I sitting heard the astronomer where he lectured with much applause in the lecture-room,
How soon unaccountable I became tired and sick,
Till rising and gliding out I wander'd off by myself,
In the mystical moist night-air, and from time to time,
Look'd up in perfect silence at the stars.

Rest in peace Beverly, my dear friend. We will always remember your tremendous contributions to astronomy.

Rodney Pommier *is a surgeon and astroimager who was recently elected a Fellow of the Royal Astronomical Society.*

BELOW: LDN 1111, silhouetted against IC 1396 in Cepheus, is a dark nebula for which few people would be expected to know the shape.

DISCOVER GREAT NGC STAR CLUSTERS

If you've never strayed beyond Messier objects, this list will be a revelation. TEXT AND IMAGES BY ROBERT REEVES

This is a tale of rediscovery. I have been an astronomer for more than half a century. My current observing concentrates on showcase nebulae and galaxies or the pursuit of fine lunar detail. But recently, I had a reawakening that transported me back to when I received my first "serious" telescope, a 4-inch reflector, at Christmas 1960.

At the time, I lived on a ranch midway between San Antonio and Laredo, Texas. To say that night sky was dark is to reminisce about what few modern astronomers have experienced. My other Christmas gift, Antonin Becvar's *Atlas of the Heavens*, was hot off the press. I saw the thousands of *New General Catalogue* (NGC) objects plotted in the atlas as a roadmap to the stars.

The real-world sky

The NGC is a listing of 7,840 celestial objects compiled in 1888 by the Danish astronomer John Louis Emil Dreyer. The catalog was an expansion of William and Caroline Herschel's 18th-century

The author poses with his Celestron Origin telescope on his home observing deck in San Antonio.

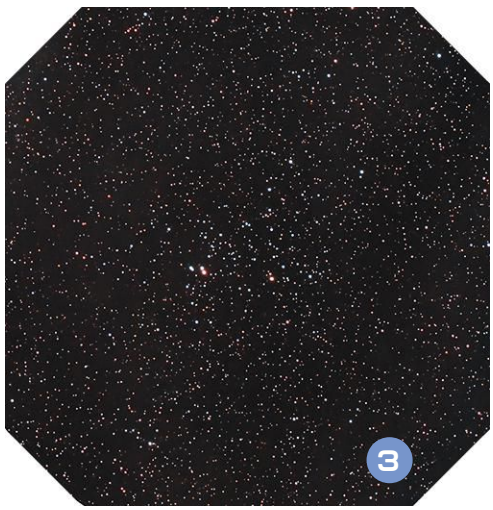
1 NGC 6819 is a magnitude 7.3 open cluster that contains some 900 stars. It's so rich, at low magnification it can be mistaken for a globular cluster, and it appears larger than its 5' diameter. It's framed on the east by two 6th-magnitude stars, and a 10th-magnitude golden star lies on the eastern edge.

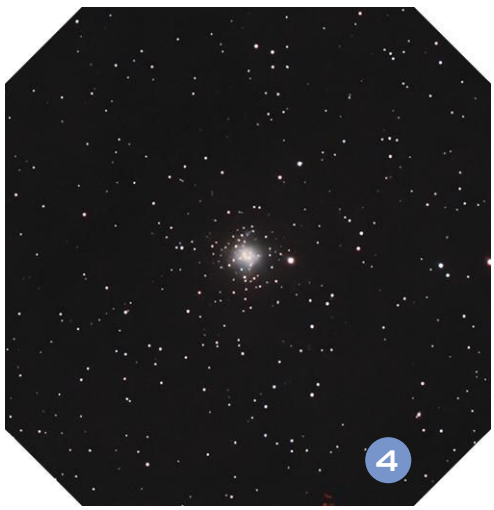
2 NGC 6633, which glows at magnitude 4.6, is an easy binocular object with a loose oval pattern of 50 stars spread across half a degree. It's punctuated on the east and west sides by arcs of triple stars and anchored on the southeast by the 5th-magnitude star SAO 123516.

3 NGC 6709 is a triangular pattern of 40 stars that appears as a hazy magnitude 6.7 glow through binoculars or a modest telescope but displays up to 100 stars in a large scope. A pair of 9th-magnitude blue and gold stars lie on the southeast corner.

4 Moderate aperture presents globular cluster NGC 6934 as a bright patch with a concentrated core. Also known as Caldwell 47, this 9th-magnitude object displays a halo of several dozen brighter stars surrounding the core.

5 NGC 6834 presents a tight egg-shaped 8th-magnitude cluster of 50 stars nested within a noticeably starless region of the Milky Way on the southern border of Cygnus.





observations and John Herschel's *General Catalogue of Nebulae and Clusters of Stars*, compiled in the 19th century. You'll quickly notice that the NGC star clusters follow the path of the Milky Way and are embedded within its hazy background, while NGC galaxies lie away from the obscuring dust and gas prevalent within the Milky Way.

The stars are just dots against the black night sky, but there is beauty in their collected pattern. Nature is a

6 Lying less than 5° from the north celestial pole, NGC 188 — also known as the Polarissima Cluster — is visible year-round from most of the Northern Hemisphere. Though broad, its 120 stars are faint, and a large aperture is needed to resolve its magnitude 12 to 15 stars.

7 A modest telescope reveals magnitude 9.3 NGC 7142 as a loose cluster of about 100 stars lying 0.5° southeast of the reflection nebula NGC 7133. Although cataloged as only 5' in size, NGC 7142 presents a larger appearance.

8 NGC 7419 requires a big scope to resolve the cluster's elongated and dim spread of 40 stars, but the effort is rewarded by a beautiful scene. Although populated with blue and white stars, the numerous red stars sprinkled across the cluster inspired the name the Golden Cluster.

9 Caroline's Rose (NGC 7789) appears much larger than its cataloged 15' size and outclasses many of the clusters in Messier's catalog. This homogeneous cluster of hundreds of faint stars is a delight in binoculars and any telescope.

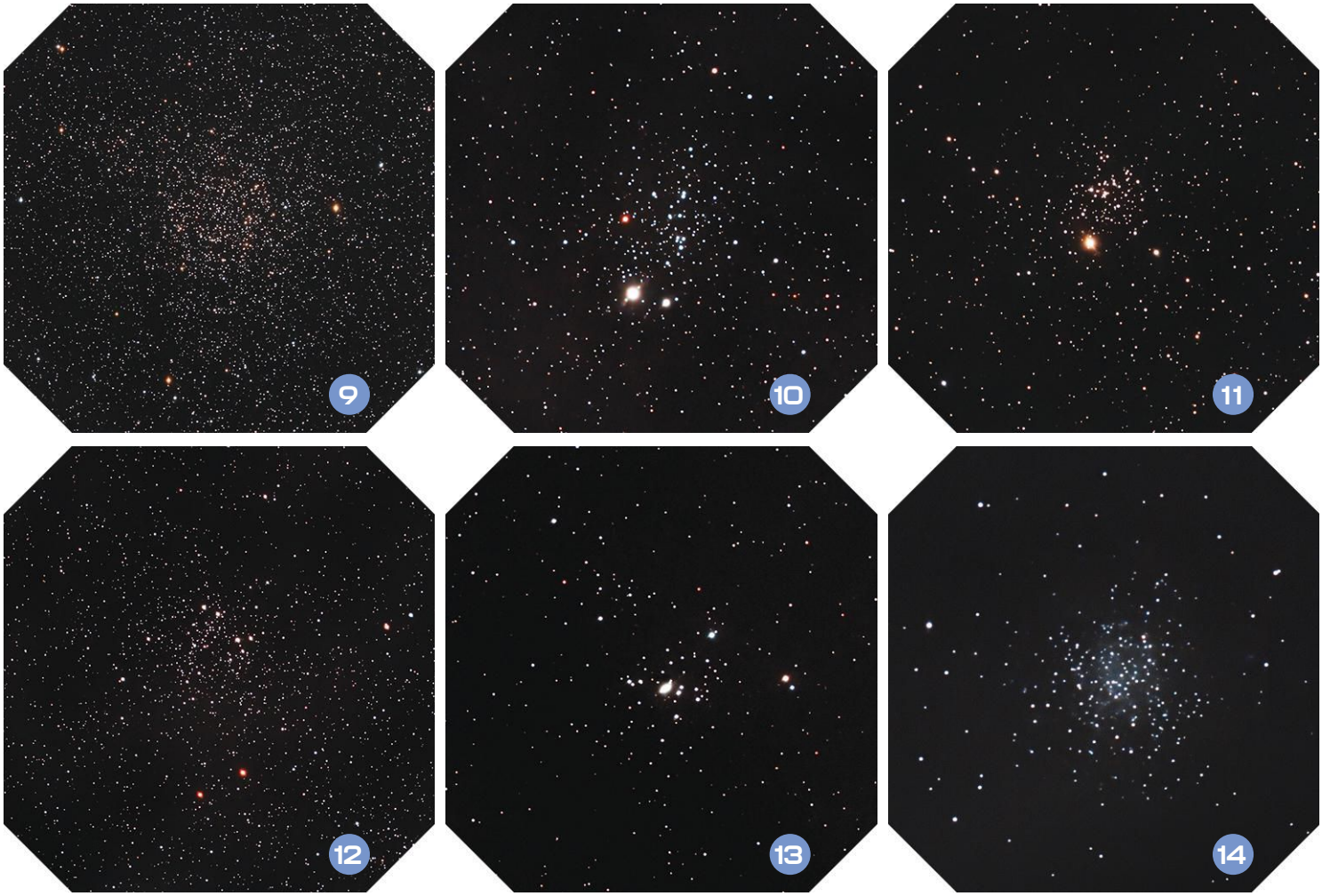
10 The bright double star Phi (ϕ) Cassiopeiae overlays the southern edge of the Owl Cluster (NGC 457), which most observers agree renders it one of the most beautiful of the many star clusters splashed across Cassiopeia.

11 Magnitude 6.5 NGC 654 is a richly concentrated knot of 60 stars bordered on the south by the yellow magnitude 7.3 star SAO 11950.

12 NGC 663, which glows at magnitude 7.1, lies ¾° southeast of NGC 654. NGC 663 displays 80 stars through a large telescope with a finger of dark, obscuring dust extending from the north and bisecting it. Adding to the visual intrigue, the cluster is framed by twin reddish stars to the southwest and bright red and blue stars to the northwest.

13 NGC 1502 presents a loose triangular spread of 45 stars punctuated by a belt of brighter stars along the southeastern edge. Twin 7th-magnitude stars lie within 16" of each other and visually merge to create an attention-grabbing brighter star on the cluster's southeastern edge.

14 NGC 288 is one of the larger globular clusters that escaped Messier's attention but is certainly worthy of being in his catalog. It appears as a hazy core surrounded by a sparkling halo of dozens of stars spread primarily to the southeast.



talented artist, and her starry creations are enchanting.

To the novice, most NGC objects bear a cold numeric designation — though some NGC clusters also have nicknames, notable examples being Caroline's Rose (NGC 7789) and the Owl Cluster (NGC 457), both in Cassiopeia. The smaller but more famous Messier catalog can be considered the glamorized "Hollywood" version of the sky, filled with leading ladies and heartthrobs with endearing nicknames that excite all astronomers. But the NGC is the real-world sky, filled with the supporting actors that complete the cosmic theatrical production.

Picking out a favorite cluster is a subjective thing, but its aesthetic beauty carries more weight than its size. Some appear as a bright splash of stars in front of a fainter starry backdrop. Others are shrinking violets that hide behind a shower of brighter foreground stars, almost indistinguishable from the starry background. An artistic small star pattern can be more endearing than a larger scattershot star pattern. Colorful or bright foreground stars can transform an otherwise mediocre cluster into a charming piece of celestial jewelry.

Imaging some clusters

Recently, I acquired a Celestron Origin telescope, a new entry in the growing field of smart telescopes. I appreciate the aesthetics of a stunning eyepiece view, but the realities of a four-hour round trip to reach a dark site make purely visual observing an infrequent event. I quickly discovered that from a bright urban environment, the Origin, an instrument made for imaging, can transmit stunning images to my smartphone.

The Origin's onboard processing produced images that look like views through a 20-inch telescope under a dark sky. I was amazed at how the Origin swept up hundreds of beautiful nebulae and clusters despite being landlocked within an island of urban light pollution.

I captured the images in this story with my Origin from the center of San Antonio, Texas, a city of 2 million people. The only modification I made to the Origin was to install Celestron's nebula filter specifically designed for the instrument.

The arc of the summer Milky Way in Cygnus to Sculptor in the fall season offers many alternatives to the familiar Messier objects. When I acquired the Origin telescope in July, both Sagittarius and Scorpius were behind trees as seen from my observatory, so I began reacquainting myself with the best clusters in Ophiuchus.

I think these NGCs rival their Messier counterparts. I invite you to observe them and see if you agree. Happy star hunting!

Robert Reeves *is a longtime amateur astronomer and astroimager who loves pushing new equipment to its absolute limits.*

The RedCat 91mm refractor wears a sleek black design with sharp red details — perfect to match its superior performance. WILLIAM OPTICS

THE REDCAT 91 is a refractor everyone should want

William Optics' newest refractor captures pinpoint stars and fine detail for imagers.

BY FRANK DIBBELL

Wide-field imaging is a passion of mine. Something about capturing a large swath of the night sky filled with delicate billows of ionized hydrogen stimulates the imagination and creates a sense of awe at the beauty of our universe.

For two years, my favorite wide-field refractor has been my William Optics RedCat 71, but I've sometimes wished it could produce a little more resolution on some of those intricate patterns of nebulosity. When I heard that William Optics was releasing a 91mm f/4.9 version of the RedCat, I wondered if this might be the refractor that gives me what I wanted.

My first impression after receiving my scope is that the RedCat 91 is a well-crafted astronomical imaging refractor, with a machined aluminum finish and quality feel. Its size (less than 22 inches [56 centimeters] long) and weight make it portable. It comes mounted in a ring system with a Vixen dovetail plate on the bottom and a handle on the top for easy carrying. The handle also serves as a mounting shoe for a guide scope.

Optically, the RedCat 91 is superb. Its focal ratio of f/4.9 makes it a fast photographic system and its 55mm image circle easily covers a full frame sensor. It also utilizes the Petzval design, which produces a nice flat field without the need for a special "field flattener." For me, that is a major feature. Standard apochromatic refractors produce curved light cones, which result in warped stars near the edge of the field. This curvature makes the use of a field flattener a necessity — and they can be quite frustrating to use. Getting the proper flattener-to-sensor distance involves trial and error and the tolerances are often less than 1 millimeter.

The RedCat 91's field of view is not quite as broad as my RedCat 71. However, a quick test using the Framing Wizard of the popular automation application Nighttime Imaging 'N' Astronomy shows the RedCat 91 still covers a respectable field of 4.6° by 3.1° with a full frame camera. This is enough sky real estate to easily frame all of the Andromeda Galaxy (M31), or the rich field in Auriga that encompasses the Flaming Star Nebula (IC 405), the Tadpoles (IC 410), and the Spider and the Fly (IC 417 and NGC 1931).

Extras included

One of the most attractive features of the RedCat is its unique focuser, the patented William Optics Internal Focus Design (WIFD). This design places the focuser within the optical tube near the center of balance, providing two major benefits. First, it secures the focuser in a dust-free environment, thus eliminating the need for frequent cleaning. But most importantly, it eliminates balance issues when adding or changing imaging equipment. And it is just as easy to attach an electronic focusing mechanism to the WIFD as it is to a traditional rack-and-pinion focuser.

This RedCat comes with two imaging camera adapters: an M54 for full-frame

sensor cameras and an M48 for APS-C sized sensor cameras. These adapters also provide T-mount support, making the RedCat compatible with various brands of DSLR and mirrorless cameras when paired with a matching T-ring.

The RedCat 91 has a manual field rotator and image tilt adjuster, which is very useful if the sensor is not perpendicular to the imaging axis. Finally, the lens cap contains a built-in Bahtinov mask for easy manual focus.

Standing ovation

My RedCat 91 came with a promotional Uniguide, a 32mm f/3.75 guide scope that connects to the handle on top of the refractor's rings. To complete my setup, I attached my full-frame CMOS camera with its 50mm filter wheel using the supplied M54 adapter. I was pleased to discover that there was enough back focus to add an electronic rotator, with about 8mm to spare.

On my first night out, I aligned the system and easily brought it to focus using the Bahtinov mask. The RedCat 91 holds focus well; I didn't notice any shift as the temperature dropped through the night.

Clouds shut down my evening activities, so first light would have to wait. When I got my clear night, I chose IC 2177, also known as the Seagull Nebula, as my target. For my imaging run I took a set of RGB light frames — 12 frames per filter at 300 seconds each. Next I took a series of Hydrogen-alpha (Hα) frames — nine at 900 seconds each. Finally I shot a series of Oxygen-III (OIII) frames — 12 at 1,200 seconds each. All data captured was binned 2x2 to limit the file size of each light frame. In total, I spent two nights collecting my data.

The first thing I wanted to check was the star geometry: How do the stars look across the entire frame of the image? For that test, I processed the RGB data first, creating a simple RGB image. After enlarging the image, I checked the stars at the extreme edges, and was pleased to see that the stars remained perfectly round across the entire field.

Then, to see this scope's full capabilities, I added the narrowband Hα and OIII data to the image. The RedCat 91 easily pulled in fine structural details only visible in narrowband light to create an absolutely impressive result.

Trial and little to no error

I am impressed with the performance of the RedCat 91. It produces wonderful deep-sky images that can cover a full-frame sensor, showing no aberration to star geometry at the edges of the field. Its Petzval design produces a truly flat field and eliminates the need for special flatteners and the issues surrounding them, such as proper flattener-to-sensor spacing.

The RedCat 91 does not come with an external guide scope, though William Optics was offering a free promotional 32mm UniGuide when I received mine and at the time of writing this review. I found star focusing a challenge with the 32mm UniGuide and would personally recommend purchasing the larger 50mm UniGuide, as it has a longer focal length and larger aperture, making the stars easier to bring to focus.

For those who prefer off-axis guiding instead of an external guide scope, back focus will be an issue. Using a standard CMOS camera with a filter wheel, there is about 24mm of back focus available. That's not enough for a large off-axis guider (OAG), which would be needed with a full-frame camera. The OAG itself may fit, but the guiding camera unit atop the OAG spans 50mm and will not clear the back of the RedCat when installed. On the other hand, the RedCat's focal length is short enough at 448mm and the image scale used is such that an external guide scope works just fine. The refractor offers plenty of room to add an electronic field rotator, which is a necessity if you wish to make the RedCat 91 the centerpiece of a robotic system.

William Optics provides a manual for the RedCat 91 available online and downloadable as a PDF file. This manual covers all aspects of the scope, including how to use the tilt adjuster and mount external devices such as an electronic focuser.

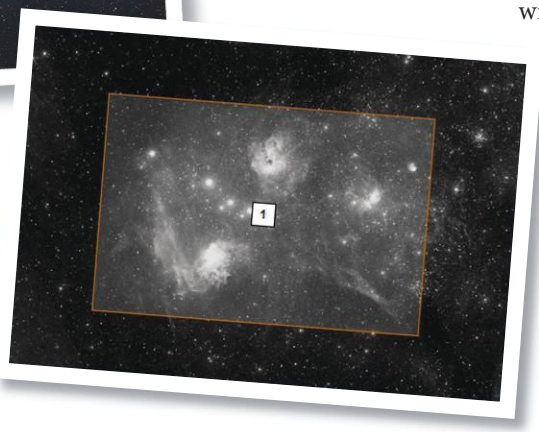
In conclusion, the RedCat 91's portability makes it perfect for field use as a wide-field imaging refractor. For those who have the luxury of a backyard observatory, the RedCat lends itself well to full automation as a semi-permanent observatory telescope, or even as part of a robotic imaging system at a remotely hosted observatory.

***Frank Dibbell** is an avid imager and docent at the local community observatory in Placerville, California.*

PRODUCT INFORMATION

WIFD RedCat 91 APO Refractor
Focal length: 448mm
Focal ratio: f/4.9
Aperture: 3.6 inches (91 mm)
Image circle: 55mm
Weight: 13.9 pounds (6.3 kg)
Price: $2,598.00
Contact: wo@williamoptics.com

ABOVE: The Seagull Nebula (IC 2177) is stunningly photogenic when imaged with William Optics' WIFD RedCat 91 APO Refractor. FRANK DIBBELL



RIGHT: The Flaming Star Nebula (IC 405), the Tadpoles (IC 410), and the Spider and the Fly (IC 417 and NGC 1931) comfortably fit within the frame of the RedCat 91 — a field of 4.6° by 3.1° with a full-frame camera. FRANK DIBBELL

Imaging filter basics

The right choice will enhance your images.

LEFT: Here is a different perspective of the Orion Nebula (M42). The author used the Antlia ALP-T dual-band SII/Hβ filter, a 9.25-inch Celestron Edge HD scope, a ZWO ASI2600MC Pro camera, and one hour of exposures. MOLLY WAKELING

RIGHT: This image shows the author's monochrome filter wheel with 2" mounted Optolong LRGB and 3nm Hα, OIII, and SII filters. MOLLY WAKELING

BY MOLLY WAKELING

Molly is an avid astrophotographer active in STEM outreach. She has a Ph.D. in nuclear engineering.

Astrophotography is a hobby with a huge learning curve, and one aspect that can muddy the waters is the dizzying array of filters on the market. What is narrowband? What size do I need? Which are good for monochrome and one-shot color? Let's cover some of the basics.

There are two types of filters for astrophotography: narrowband and wideband (some say broadband, but I think this is too similar to the term for high-speed internet). Wideband filters cover large swaths of the optical light spectrum, and while they are most commonly used for star clusters and galaxies, they can be used for any kind of target. For monochrome cameras, these filters include luminance, red, green, and blue (LRGB) filters, as well as light-pollution filters such as the Optolong L-Pro and Astronomik CLS-CCD, which are also applicable to one-shot color (OSC) cameras. Also, you can use a light-pollution filter as the L channel for monochrome cameras.

Determining what size filters you need can be difficult for beginners.

Narrowband filters pass only small slices of the optical spectrum centered around emission lines, which makes them excellent for imaging nebulae under light pollution. The three most common narrowband emissions are Hydrogen-alpha (Hα) at 656.3 nm (red), Oxygen-III (OIII) at 495.9 and 500.7 nm (blue-green), and Sulfur-II (SII) at 672.4 nm (deep red). There are also other less commonly used filters, such as Hydrogen-beta (Hβ) at 486.1 nm (blue). For monochrome cameras, filters that pass only one of these wavelengths are the most useful so the images can be individually colored. If you use Hα, OIII, and SII, you can make Hubble-palette images by assigning SII to red, Hα to green, and OIII to blue.

For OSC cameras, filters that transmit multiple bands are best to get some light on all the red, green, and blue pixels together. Dual-narrowband filters are the most common, such as the Optolong L-Ultimate and Antlia ALP-T Hα & OIII, which have 3nm and 5nm bandpasses, respectively, around the Hα and OIII wavelengths. At a higher cost are quad-band filters, such as the Optolong L-Quad and Antlia Quad Band, which pass Hα and OIII as well as SII and Hβ. On an OSC camera, it's difficult to distinguish Hα and SII since they are both red, and OIII and Hβ, which are both in the blue, but because these filters pass more wavelengths you can get more light on targets such as planetary and emission nebulae, and supernova remnants.

Determining what size filters you need can be difficult for beginners. There are several common sizes available: 1¼", 31mm, 36mm, 50mm, and 2". Those with sizes in inches are mounted filters, which means they come in a threaded housing you can easily screw into a filter wheel or onto the end of some nosepieces or extension tubes. The metric-sized ones are generally unmounted, which can only go into a filter wheel.

The driving factor behind which size filter you need is the size of your camera sensor. Full-frame cameras, such as the ZWO ASI6200MM Pro, are 43 mm long on the diagonal, so 1¼", 31mm, and 36mm filters will block the corners of the sensor and cast a shadow. On the other hand, 4/3-size sensors like on the ZWO ASI1600MM Pro are only 22 mm along the diagonal, so even 1¼" and 31mm filters will cover the entire sensor. Even though I don't have a full-frame astrophotography camera yet, I invested in 2" and 50mm filters (and their corresponding filter wheel size) from the start to avoid having to buy a whole new set of filters later, but larger filters and filter wheels can be significantly more expensive than their smaller counterparts.

Having the right filter for the right job is an important component of creating a good astrophoto. Choosing the type and size for your camera and target will help you capture all those incredible celestial objects that lie buried in the deep sky.

BROWSE THE "OBSERVING BASICS" ARCHIVE AT
www.Astronomy.com/author/molly-wakeling

NEW PRODUCTS

Mobile mount

Vixen
Saitama, Japan

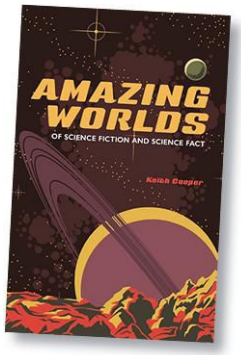
The Mobile Porta Mount is the new, easily portable piece in the popular Porta line. The alt-azimuth accessory has friction stop motion to locate objects quickly. Telescopes weighing up to 7.7 pounds (3.5 kilograms) can be attached. The mount head can be detached and the multiarm can be folded, both for ultimate portability.

$215.99
1-866-252-3811
https://global.vixen.co.jp/

Attention, manufacturers: To submit a product for this page, email **products@astronomy.com**.

Fact and fiction

Reaktion Books
London, United Kingdom



In *Amazing Worlds of Science Fiction and Science Fact*, science journalist Keith Cooper explores the exoplanets found in popular media. Over a dozen scientists and authors weigh in as Cooper analyzes how realistic the fictional planets are in *Star Wars*, *Avatar*, *Dune*, and more. The 224-page book also contains 12 illustrations.

$22.50
info@reaktionbooks.co.uk
https://reaktionbooks.co.uk

Small and strong

ZWO
Suzhou, China

Seestar introduces the new S30. This smart telescope and camera weighs only 3.6 pounds (1.7 kg), but features a 150 mm focal length and 64 gigabytes of storage. Good for shooting deep-sky objects, it includes an extra-low dispersion lens and noise filtering. It also comes with Wi-Fi and Bluetooth capability to access the Seestar app from anywhere.

$349.00
info@zwoptical.com
www.zwoastro.com

INDEX *of* ADVERTISERS

ADM Accessories 51
Adventures in Astronomy Inc 5
Bob's Knobs 51
Celestron 60
Cosmic Collectibles 11
Don Logo 11
Lazy Bear Expeditions 2
Mason Capital Partners 11
Metamorphosis Jewelry Design 51
Oberwerk 11
Rainbow Symphony 51
Scope Buggy 6
Snow King Mountain Resort 6
The Space Store 59

The Advertiser Index is provided as a service to *Astronomy* magazine readers. The magazine is not responsible for omissions or for typographical errors in names or page numbers.

Want more *Astronomy*?

INSIDE THE MILKY WAY'S VIOLENT FORMATION
Astronomy
10 GREATEST MYSTERIES OF THE COSMOS
IS THE UNIVERSE EXPANDING FASTER THAN PREDICTED?

Get your FREE weekly *Astronomy* newsletter delivered to your inbox!

Astronomy

Go to **Astronomy.com/magazine/newsletter** for more info.

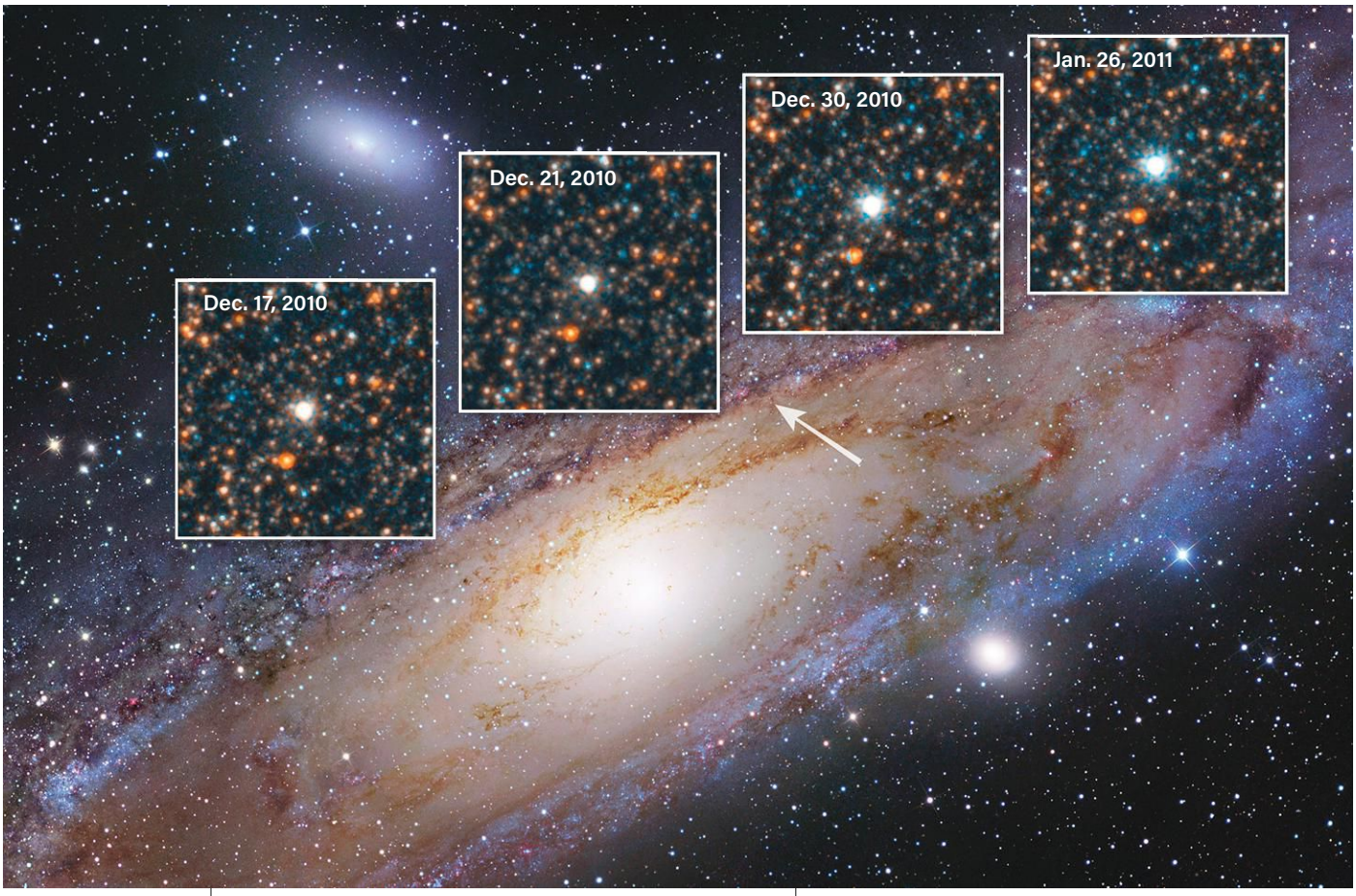
Fine Meteorite Jewelry
In Gold & Platinum
www.NinePlanetsRing.com

ADM
$69
Vixen dovetail to Synta Dovetail female to female clamp.
ADM ACCESSORIES
www.admaccessories.com

ECLIPSE SHADES™
Safe Solar Viewers
CE Certified
SAFE FOR DIRECT SOLAR VIEWING
Rainbow Symphony, Inc.
818-708-8400 • Fax 818-708-8470
www.rainbowsymphony.com

Bob's Knobs™
COLLIMATION THUMBSCREWS
www.bobsknobs.com

MARKETPLACE



By studying a Cepheid variable star within the Andromeda Galaxy, Edwin Hubble proved that Andromeda was too far away to be a nebula within the Milky Way. Here, the insets show that same variable star over time as it brightens and dims.
NASA, ESA, HUBBLE HERITAGE PROJECT (STSCI, AURA; ACKNOWLEDGMENT: ROBERT GENDLER

Variable stars

Q HOW DID A CEPHEID VARIABLE STAR HELP EDWIN HUBBLE PROVE THE ANDROMEDA NEBULA WAS A GALAXY?

Roger Brady
San Quentin, California

A Cepheids are rare variable stars with periods ranging from about 1 to 120 days. Their light curve — a chart showing brightness over time — is characterized by rapid brightening followed by slow dimming in a distinctive pattern, making them easy to identify. In the early 1900s, Henrietta Swan Leavitt of Harvard College Observatory examined photographic glass plates of the Magellanic clouds and discovered a record 1,777 new variable stars, some of which were Cepheids. Her brilliant observation was that the longer a Cepheid's period, the brighter it became at maximum. She correctly assumed that because the Cepheids were all contained within a single deep-sky object, namely in one of the Magellanic clouds, they must all lie at roughly the same distance from Earth. That meant their apparent magnitudes (the magnitude we measure at the telescope, as brightness is affected by distance) were accurate indications of their true luminosities (the intrinsic brightness of the star). In 1912, she published a landmark graph based on 25 Cepheids within the Small Magellanic Cloud showing a linear correlation between the logarithm of their periods in days and their average apparent magnitudes. This is now known as the period-luminosity relationship, or Leavitt law, and it is one of the most important principles in astrophysics.

Danish astronomer Ejnar Hertzsprung realized the tremendous significance of Leavitt's discovery. If the distance to any Cepheid could be determined, then you could use its apparent magnitude and distance to figure out how bright it really is. That would enable calibration of Leavitt's graph with absolute magnitudes (inherent brightness) rather than apparent magnitudes (observed brightness). From then on, the distance to any Cepheid could be determined using only two pieces of data: its period and its apparent magnitude. Hertzsprung

calculated the distances to 13 Cepheids, including the prototype star Delta (δ) Cephei, using the technique of statistical parallax (which uses the motion of Earth around the Sun to calculate a star's distance based on how much it shifts against more distant background stars) and calibrated Leavitt's graph with absolute magnitudes.

When Edwin Hubble discovered a Cepheid within the so-called Andromeda Nebula he knew he'd struck astronomical gold that would enable him to calculate its distance. From serial photographic glass plates, he measured its period to be 31.415 days and its average apparent magnitude to be 18.5. A calibrated period-luminosity graph indicated a Cepheid with a period of 31.415 days has an absolute magnitude of –5.0. For a star with absolute magnitude of –5.0 to have an apparent magnitude of 18.5, it would have to be incredibly far away. The distance he calculated was well outside the bounds of the Milky Way as they had been recently measured by Harlow Shapley at Harvard College Observatory, proving it had to be another galaxy.

FROM THEN ON, THE DISTANCE TO ANY CEPHEID COULD BE DETERMINED USING ONLY TWO PIECES OF DATA: ITS PERIOD AND ITS APPARENT MAGNITUDE.

For a more detailed explanation of this, see my article in the August 2022 issue of *Astronomy* describing how I reenacted Hubble's work with my backyard telescope and CCD camera and precisely reproduced his results.

Rod Pommier
Astroimager and Astronomy *contributor, Portland, Oregon*

Q | WHY WILL OUR SUN EXPEL ITS OUTER LAYERS AS IT DIES?

Daniel Stanyer
Augusta, Kansas

A | First, let's discriminate between expansion and expulsion. Expansion happens because the thermal pressure from the increased energy production in the Sun's interior exceeds the gravitational force keeping the Sun's matter close to its core. The Sun will expand until a new equilibrium between pressure and gravity is established. This process is ongoing and can continue gradually for billions of years.

Expulsion is a different matter. Massive stars expel their outer layers in a supernova detonation, while low-mass stars like our Sun will do so in what is called the planetary nebula phase. The difference has to do with what is going on in the star's core.

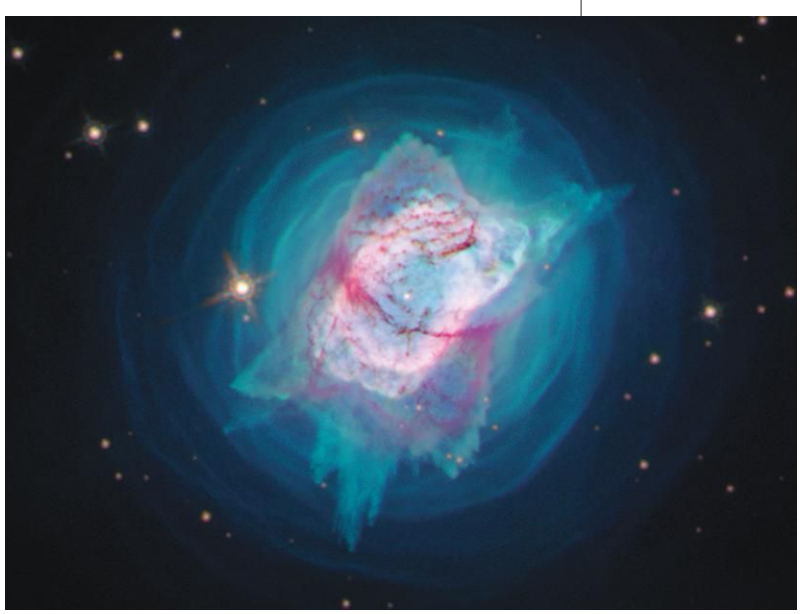
For billions of years, the Sun's core has been fusing hydrogen into helium, which has then settled as an "ash" deeper into the core region. As the core continues to collapse under its own weight, its heats up the interior of the Sun to higher and higher temperatures. The Sun adjusts to this increased energy production by slowly expanding in size and luminosity, becoming a red giant star. Eventually, the core temperature reaches 100 million kelvins, and helium ash begins to fuse into carbon in the triple-alpha process (during which three helium nuclei fuse into one carbon nucleus).

If the triple-alpha reaction happens in a high-mass star, most of the released energy goes into heating the helium-ash core, which is a plasma. The massive star expands to another equilibrium size and all is well. However, if it is a low-mass star like our Sun, most of the energy goes into heating the core, which by now is made of degenerate "white dwarf" matter — meaning it cannot be further compressed, nor can it expand to cool off when the temperature increases. When the core is heated in such a star, it begins to once again act like a normal plasma and expands. But some of the energy also goes into heating the Sun's outer layers, which rapidly expand away from the star as a dense stellar wind. This post-red-giant phase is usually called the planetary nebula phase and lasts only about 50,000 years or less. In the end, you have the cooling white dwarf core of the star, a powerful source of ultraviolet light, causing the ejected gas to fluoresce as a planetary nebula for a few thousand years.

Sten Odenwald
Senior Outreach Coordinator, NASA HEAT Program, Kensington, Maryland

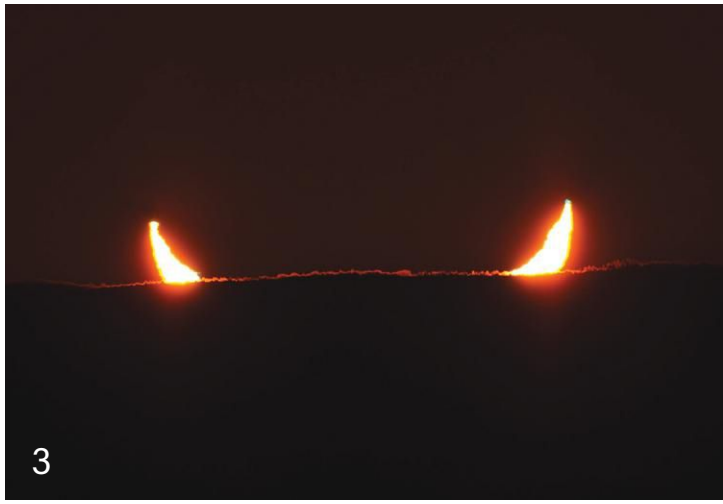
SEND US YOUR QUESTIONS

Send your astronomy questions via email to **askastro@astronomy.com**. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.



NGC 7027, known as the Jewel Bug Nebula, is an example of a planetary nebula that arises as mass is expelled from an aging star, as will happen to our Sun in the future. NASA, ESA, JOEL KASTNER (RIT)

1



1. A GALACTIC MEGACONGLOMERATE
The galaxy Fornax A (NGC 1316) is famed for its enormous radio lobes, but deep optical imaging reveals dizzying layers of structure generated by a series of mergers that made the galaxy what it is today. Just right of Fornax A is the smaller spiral NGC 1317, likely to be the larger galaxy's next acquisition. The imagers used a 20-inch reflector to collect 43 hours of LRGB data. ***• Team ShaRA***

2. A (REALLY) LONG EXPOSURE
In this solargraph, the Sun's journey across the sky is captured continuously for 43 days, its trails interrupted by overcast days and passing clouds. To create the image, the photographer transformed a beer can into a pinhole camera and lined the interior with light-sensitive photographic paper. In the foreground is the facade of the Museum of the Moving Image, a contemporary structure located within the wall of the medieval castle of Leiria, Portugal. ***• Rui Santos***

3. HORNS OF THE SUN
The partial solar eclipse of March 29 gave viewers along the U.S. Eastern Seaboard a view of "devil's horns" — the cusps of a partially eclipsed Sun emerging from the horizon at sunrise. This photographer captured the phenomenon from Monticello, Maine, with a 4-inch f/7 refractor and Nikon DSLR. ***• Fabrizio Melandri***

4. A SOUTHERN TARGET
RCW 85 is a faint emission nebula in the southern constellation Centaurus. Its designation comes from a catalog of Hα emission regions published in 1960 by a trio of researchers working in Australia under the astronomer Bart Bok: Alexander Rodgers, Colin Campbell, and John Whiteoak. This SHORGB image was taken with at 24-inch scope and 5 hours of exposure, 3 hours of which was in Hα. ***• Kfir Simon***

5

6

7

8

5. BLOOD GLOW
The visual appearance of the March 13/14 total lunar eclipse was captured in this composite of three stacks of images: One for the eclipsed Moon, one for the background star field, and a third stack of overexposed frames to capture the diffuse glow around the Moon. The imager used a 4.5-inch refractor at f/5.6 and RGB filters. ▪ ***Steve Leonard***

6. COSMIC FLEDGLING
This dusty figure of the Baby Eagle Nebula (LBN 777) is part of the larger Taurus Molecular Cloud. The dust is dimly lit by young stars within the cloud; the brownish color gives away the presence of larger dust grains. This image comprises nearly 24 hours of LRGB exposure with a 5-inch scope. ▪ ***Greg Meyer***

7. UPON FURTHER REFLECTION
Reflection Canyon, located at the end of an 8-mile hike into Utah's Grand Staircase Escalante National Monument, serves as the foreground for this view of the spring Milky Way. The photographer captured the sky with a Canon mirrorless camera and a 15-second exposure at f/1.8 and ISO 4000 with a 24mm lens. The foreground is a separate 2-second exposure at blue hour at f/11 and ISO 200. ▪ ***Pete Scifres***

8. A FLEDGLING SWAN
Comet C/2025 F2 (SWAN), discovered March 29 by amateur astronomers in public imagery taken by the Solar Wind Anisotropies (SWAN) camera on ESA's Solar and Heliospheric Observer spacecraft, reached magnitude 8 in early April. This imager caught the comet near its peak brightness the morning of April 8 with an 8-inch Celestron RASA scope and 22 minutes of exposure with a one-shot color camera. ▪ ***Chris Schur***

SEND YOUR IMAGES TO: readergallery@astronomy.com.
Please include the date and location of the image, your mailing address, and complete photo data: telescope, camera, filters, and exposures.

A HAUNTINGLY BEAUTIFUL SWAN SONG

About 10,000 years ago, a new star appeared in what we now recognize as Cygnus the Swan. It was the light from a supernova explosion that occurred about 2,400 years earlier, when a star with roughly 20 times the Sun's mass had exhausted its nuclear fuel. This caused the core to collapse, triggering a shock wave that tore the rest of the star apart. When the light reached Earth, it shone brighter than Venus and would have been visible during the day; today astronomers see the tattered remains of the star as the Veil Nebula, a glowing cloud of gas that spans 3°, six times the Full Moon's diameter. The Hubble Space Telescope captured this tiny section of the Veil located near the nebula's southeastern edge. The image combines light emitted by hydrogen, sulfur, and oxygen atoms. ESA/HUBBLE & NASA, R. SANKRIT

the space store®

Explore the Universe

The Space Store offers an extensive selection of space mission patches, rocket and airplane models, meteorites, toys, books, and unique items from NASA, SpaceX, Boeing, and the U.S. Space Force.

Come and check out the largest retailer of NASA and space-themed collectibles, apparel, and gifts, serving enthusiasts of all ages!

Shop now at: TheSpaceStore.com/Shop

connecting you to the cosmos

CELESTRON®

PACK YOUR BAGS

for Long Days and Starry Nights

Whether you're heading to the mountains, the desert, or your own backyard, pack your Celestron gear and experience unforgettable summer moments.

Scan to discover the perfect gear at **celestron.com/summer**

STAR PARTIES

Celestron travel bags keep your gear protected and organized, so you can focus on the sky—not the setup. With options to fit most telescopes, you'll roll in ready to observe.

CELEBRATIONS

Looking for a standout gift or a unique way to elevate your next summer gathering? Bring a telescope to the party and share the wonder of the night sky with friends and loved ones.

CAMPING TRIPS

Hit the trails with a compact, lightweight binocular or spotting scope and witness nature in motion. A smartphone adapter lets you capture the scene just as you see it through the eyepiece.

CELESTRON PREMIER SELECT DEALERS

B&H Photo – 800.947.9970 – bhphotovideo.com
High Point Scientific – 800.266.9590 – highpointscientific.com
Astronomics – 800.422.7876 – astronomics.com
Woodland Hills – 888.427.8766 – telescopes.net
Adorama – 800.223.2500 – adorama.com
Mile High Astronomy - 877.279.5280 - milehighastro.com
Focus Camera – 800.221.0828 – focuscamera.com
Agena AstroProducts – 562.215.4473 – agenaastro.com
Orange County Telescopes - 888-471-9991 – octelescope.com

September 2025
Saturn at its best

The evening sky boasts two naked-eye planets. Start your night's viewing with ruddy **Mars**, which lies in the west as darkness falls. It treks eastward against the backdrop of Virgo, passing 2° north of the Maiden's brightest star, 1st-magnitude Spica, on Sept. 12. The Red Planet shines at magnitude 1.6, slightly fainter than the blue-white star.

Mars lies far from Earth, unfortunately, so it doesn't look like much through a telescope. It sports a featureless disk 4" in apparent diameter.

On the other side of the evening sky resides September's gem, **Saturn**. The ringed world reaches opposition and peak visibility Sept. 21, when it lies opposite the Sun in our sky and remains visible all night. The magnitude 0.6 planet moves slowly westward against the background stars of southern Pisces this month, crossing into Aquarius on the 29th.

At opposition, Saturn has a declination of –3°. After many years of oppositions occurring in the southern celestial hemisphere, this is the last time it will happen until March 2040.

Opposition also coincides with the planet's closest approach to Earth, so it looms largest when viewed through a telescope. On the 21st, Saturn's disk measures 19.4" across while the ring system spans 44.1" and tilts 1.8° to our line of sight. Saturn's four brightest moons — 8th-magnitude Titan and 10th-magnitude Tethys, Dione, and Rhea — also should be easy to see.

As Saturn starts to descend in the west during the morning hours, **Jupiter** emerges in the northeast. The giant planet resides in Gemini and appears directly below the distinctive figure of Orion the Hunter. Gleaming at magnitude –2.0, it outshines every star in the night sky.

Once Jupiter stands well clear of the horizon, aim your telescope in its direction. Even small instruments should reveal two dark equatorial belts arrayed across the planet's 35"-diameter disk. And Jupiter's four bright moons show up as points of light (assuming none are passing in front of or behind the gas giant).

Around the time twilight starts to paint the sky, **Venus** pokes above the eastern horizon. Shining at magnitude –3.9, the inner world proves unmistakable even as twilight grows brighter. Unfortunately, it looks disappointing through a telescope, showing a disk 12" across and a fat gibbous phase.

Mercury reaches superior conjunction Sept. 13 and remains hidden in the Sun's glare nearly all month. It will put on a nice evening show in October.

A total lunar eclipse graces the skies above Australasia, Asia, and Africa on Sept. 7. The umbral part of the eclipse begins at 16h27m UT (the morning of the 8th from Australasian latitudes). Totality runs from 17h30m to 18h53m UT, and the umbral phase ends at 19h57m UT.

A partial solar eclipse takes place Sept. 21 and can be seen from New Zealand and much of the South Pacific Ocean. From Wellington, the eclipse starts soon after sunrise on the 22nd. It reaches a maximum at 19h04m UT, when the Moon covers 74 percent of the Sun's diameter. The eclipse concludes at 20h15m UT.

The starry sky

The International Astronomical Union (IAU) approved official constellation boundaries nearly a century ago. So, you might be surprised that the organization did not start approving proper names of stars until 2016. Of course, hundreds of star names were in common use long before then. For example, on September evenings we can gaze at Antares (the "rival to Mars"), Altair (Aquila's luminary), and Spica (which Mars passes in the middle of the month), among many others.

I was thinking not long ago about not only the great number of named stars in some constellations but also how some constellations have few named stars — at least in the current IAU list. This led me to wonder how many constellations have *no* officially named stars, and I was surprised to find 14 of these stellar groupings. Remember that 88 constellations spread across the sky, so this number represents 16 percent of the total. It amazed me even more that an additional 16 constellations have only one star with an IAU proper name.

Those first 14 all lie in the southern half of the celestial sphere. The constellations are Caelum, Circinus, Horologium, Hydrus, Indus, Lupus, Microscopium, Musca, Norma, Pictor, Pyxis, Scutum, Telescopium, and Volans.

How about the 16 constellations with only one IAU-approved star name? The majority of these also reside in the sky's southern half. People often ask me about one of them — Corona Australis the Southern Crown — even when I do not draw attention to it during a planetarium presentation. And it's easy to see why: After gazing at Scorpius, a dark-adapted eye quickly spots the faint circlet of stars immediately east of the Scorpion's tail.

The star designated Alpha (α) Coronae Australis has the proper name Meridiana, a rather odd name suggesting that it has something to do with a meridian. This Latin name, however, can be translated as south, a shortened version of the longer name Alfecca Meridiana. This separates it from Alphecca, the brightest star in the Northern Crown (Corona Borealis). A connection does exist with a meridian, though, in the sense that people in the Northern Hemisphere see the Sun due south when it lies on the meridian.

STAR DOME

HOW TO USE THIS MAP

This map portrays the sky as seen near 30° south latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

10 P.M. September 1
9 P.M. September 15
8 P.M. September 30

Planets are shown at midmonth

MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

STAR MAGNITUDES

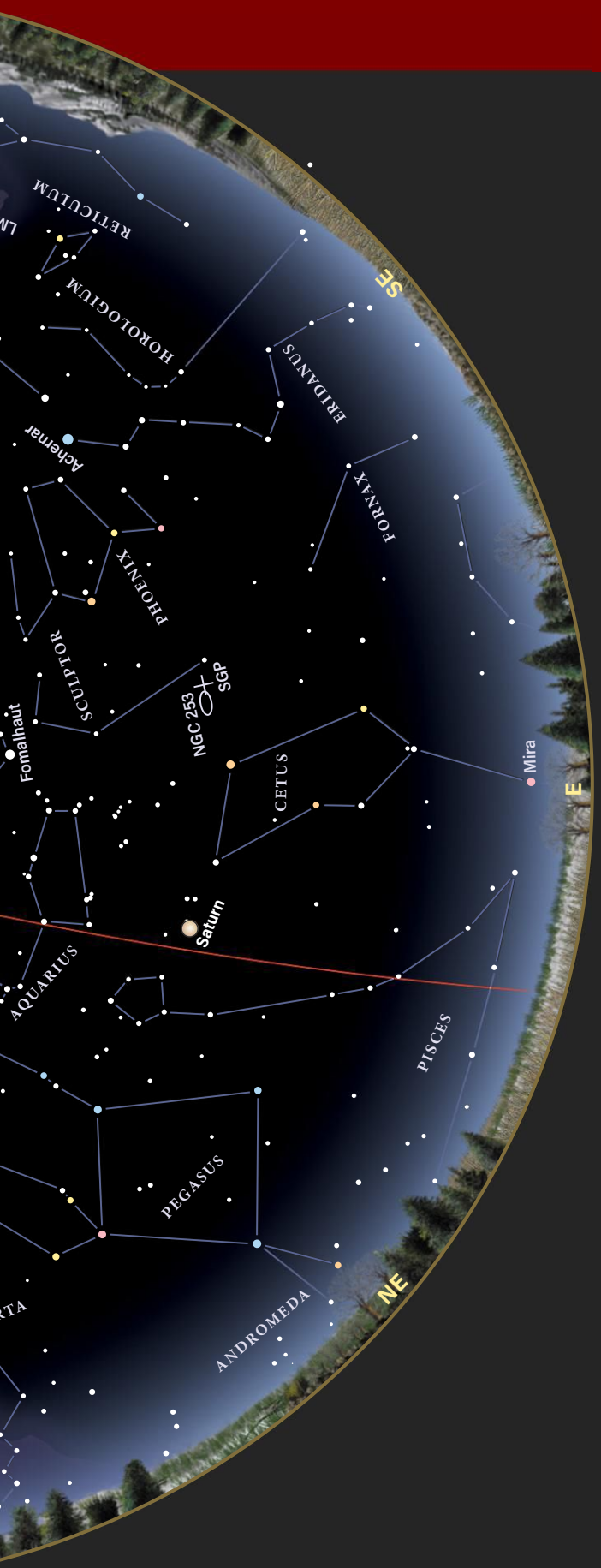
- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**



SEPTEMBER 2025

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

2 Mercury passes 1.2° north of Regulus, 0h UT

4 The Moon passes 0.06° south of Pluto, 14h UT

6 Uranus is stationary, 5h UT

7 Full Moon occurs at 18h09m UT; total lunar eclipse

8 The Moon passes 4° north of Saturn, 20h UT

The Moon passes 3° north of Neptune, 22h UT

10 The Moon is at perigee (364,777 kilometers from Earth), 12h10m UT

12 Mars passes 2° north of Spica, 8h UT

13 The Moon passes 5° north of Uranus, 2h UT

Mercury is in superior conjunction, 11h UT

14 Last Quarter Moon occurs at 10h33m UT

16 The Moon passes 5° north of Jupiter, 11h UT

19 The Moon passes 0.8° north of Venus, 12h UT

The Moon passes 1.3° north of Regulus, 12h UT

Venus passes 0.5° north of Regulus, 13h UT

21 Saturn is at opposition, 6h UT

New Moon occurs at 19h54m UT; partial solar eclipse

22 September equinox occurs at 18h19m UT

23 Neptune is at opposition, 13h UT

The Moon passes 1.1° south of Spica, 22h UT

24 The Moon passes 4° south of Mars, 15h UT

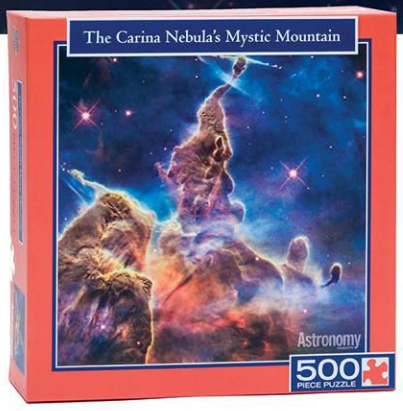
25 Asteroid Pallas is stationary, 11h UT

26 The Moon is at apogee (405,548 kilometers from Earth), 9h46m UT

27 The Moon passes 0.6° south of Antares, 18h UT

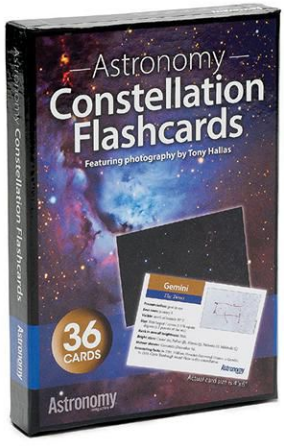
29 First Quarter Moon occurs at 23h54m UT

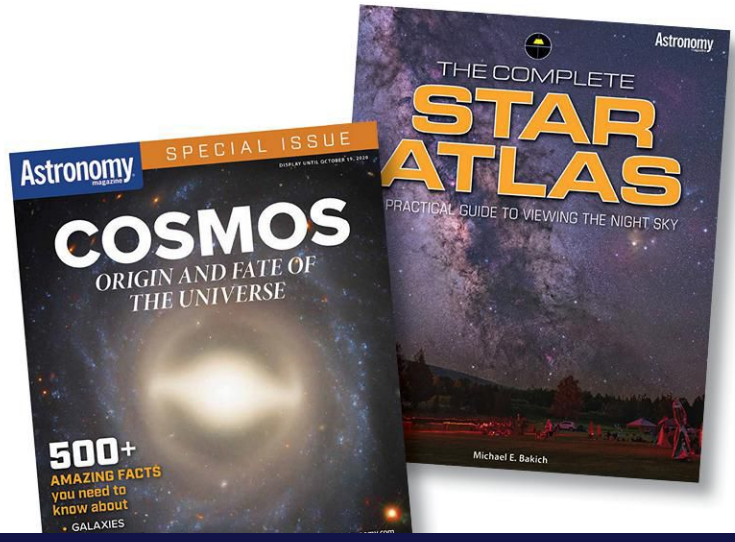
EXPLORE THE UNIVERSE



Visit TheSpaceStore.com today for high-quality astronomy products, many curated by the *Astronomy* magazine team.

- Custom-produced globes, as well as others from top manufacturers.
- Books and DVDs covering solar eclipses, observing guides, the cosmos and more.
- Magazines bringing you the latest astronomical discoveries and events.
- Collectible items to commemorate historic launches.
- Toys and games-have fun learning about astronomy!
- And much more!





space® STORE

Shop now at:
TheSpaceStore.com
Sales tax where applicable.

P39082